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| <b>(54) Title:</b> METHODS FOR CONTROLLING HUMAN ENDOTHELIAL CELL PROLIFERATION AND EFFECTOR<br>FUNCTIONS USING ONCOSTATIN M<br><br><b>(57) Abstract</b><br><br>The present invention is directed to the use of a recently discovered cytokine, Oncostatin M, to control endothelial cell im-<br>munogenicity, fibrinolytic activity, proliferation and cytokine synthesis, and to its use in the treatment of a variety of human vas-<br>cular and immune system disorders involving the vascular endothelium, as well as its use in the treatment of neoplastic disease.<br>The method of the invention includes the use of mature, hybrid, modified or truncated forms of Oncostatin M as well as Oncos-<br>tatin M analogs. The invention is described by way of examples in which the efficacy of such compounds is evaluated using var-<br>ious <i>in vitro</i> assay systems. |           |  |

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METHODS FOR CONTROLLING HUMAN ENDOTHELIAL CELL  
PROLIFERATION AND EFFECTOR FUNCTIONS USING ONCOSTATIN M

1. INTRODUCTION

The present invention is directed to the use of a recently discovered cytokine, Oncostatin M, for controlling human endothelial cell proliferation and effector functions, and to its use in the treatment of a variety of human vascular, neoplastic and immune system disorders involving the vascular endothelium. The method of the invention includes the use of mature, hybrid, modified or truncated forms of Oncostatin M as well as Oncostatin M analogs. The invention is described by way of examples in which the efficacy of such compounds is evaluated using various in vitro assay systems.

2. BACKGROUND OF THE INVENTION

2.1. EXPRESSION OF MAJOR HISTOCOMPATIBILITY COMPLEX  
ANTIGENS AND RELATIONSHIP TO IMMUNE RESPONSE

Surface-expressed proteins of the major histocompatibility complex (MHC) are integral for the initiation and effector functions of immune responses. Initiation of immune functions by CD4+ T cells (helpers) appear to require class II MHC antigen presentation, while cytotoxic effector functions by CD8+ T cells (cytotoxic T lymphocytes or CTLs) appear to require class I MHC antigen presentation. It is known that cell surface expression of MHC proteins correlates with human autoimmune and alloimmune diseases (reviewed in Feldman et al., in Interferon 9: 75-90, Academic Press 1987). Tissue cells in the majority of human autoimmune diseases including, for example, thyroiditis, diabetes, multiple sclerosis, systemic lupus erythematosus, rheumatoid arthritis, Sjogren's syndrome, vasculitis, biliary cirrhosis and immunologically-related skin disorders, as well as

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abnormally elevated levels of class I and class II MHC antigens. When cells that ordinarily do not express class II antigens (e.g., fibroblasts and endothelial cells) begin to express this class of antigen, they become

5 immunoreactive targets for lysis and destruction by CTLs (Pober et al., 1983, Nature 305: 726).

MHC antigen expression on many cell types is largely under the regulatory control of various cytokines. Cells such as macrophages, dermal fibroblasts, keratinocytes,

10 thyrocytes, astrocytes, B islet cells, smooth muscle cells, T lymphocytes, endothelial cells and many cancer cells, require induction by cytokines for class II MHC antigen expression (Revel and Schattner, in Autoimmunity and Autoimmune Disease 223-233, Wiley 1987). Members of the

15 interferon family are primarily involved with the upregulation of MHC expression and all types of interferons appear to enhance class I expression, although IFN- $\gamma$  is the best studied and most potent in this regard. In addition, the cytotoxins known as tumor necrosis factors (TNF- $\alpha$  and

20 TNF- $\beta$ ) have demonstrated the ability to enhance class I expression in fibroblasts via induction of IFN- $\beta$ 2 (May et al., 1987, Proc. Natl. Acad Sci. USA 83: 8957). While the induction of class II antigens by IFN- $\alpha$  and IFN- $\beta$  is usually not significant, IFN- $\gamma$  is a potent inducer of class

25 II molecules at the gene level (Collins et al., 1984, Proc. Natl. Acad. Sci. USA 81: 4917). Some cytokines appear to synergize with IFN- $\gamma$  in the induction of MHC antigen expression; for example, TNF- $\alpha$  and TNF- $\beta$  act

30 synergistically with IFN- $\gamma$  on expression of class I antigens on endothelial cells without affecting IFN- $\gamma$ -mediated induction of class II antigens (Lapierre et al., 1988, J. Exp. Med. 167: 794).

The level of MHC antigen expression on a cell's surface is a determinant of its antigen-presenting capacity

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(Matis et al., 1983, Proc. Natl. Acad. Sci. USA 80: 6090). Therefore, compounds that interfere with or antagonize over-expression of MHC antigens beyond immunologically-tolerated thresholds may have therapeutic utility in, for example, slowing or stopping the progression of autoimmune diseases. In the case of transplanted organs, the expression level of the donor MHC antigens is an important determinant of the severity of the rejection response (Ferry et al., 1987, Transplantation 44: 499). Transforming Growth Factor- $\beta$  (TGF- $\beta$ ) has been shown to inhibit the level of class II expression induced by IFN- $\gamma$  on human melanoma cells and peripheral blood mononuclear cells without affecting class I expression (Czarniecki et al., 1988, J. Immunol. 140: 4217).

2.1.2. ENDOTHELIAL CELL EXPRESSION OF MHC ANTIGENS:  
RELATIONSHIP TO ALLOGRAFT REJECTION

Vascular endothelial cells play a central role in the process of allograft rejection. Immunohistologic studies of tissue rejection have demonstrated that vascular endothelial cells from MHC-incompatible heart or skin express high levels of class II MHC antigens early in the rejection process (De Waal et al., 19883, Nature 303: 426-429; Milton and Fabre, 1985, J. Exp. Med. 161: 98-112). In its inception, immunologic rejection of allotransplantations involves the interaction between recipient T cells and the donor organ vasculature; other cells become involved as rejection progresses. In organ transplants the endothelium is the donor tissue which is the first target of attack by host T cells recognizing donor HLA antigens on the surface of endothelial cells. T cell infiltration through the vascular endothelium has been described as a four step process: recognition, adherence, activation, and penetration of alloactivated T cells through the vascular wall (Fung et al., 1986, Human Immunol.

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16: 182). Activated T cells produce gamma-interferon (IFN- $\gamma$ ) which stimulates the expression of class II HLA antigens on the surface of the donor endothelium, thereby transforming the donor endothelium to a more immunogenic state. Increased expression of class I antigens also results from induction by gamma-IFN and TNFs, probably augmenting the target function of the endothelium in interactions with cytotoxic T lymphocytes. In early biopsies of rejected kidney grafts, T cells with a specificity for class I HLA antigens are predominant; as rejection progresses, T cells specific for class II HLA antigens are prevalent (Zeevi et al., 1986, Transplantation 41: 620). Similar results have been found in heart transplants. The degree of alloimmune response and, ultimately, rejection depends on the expression of both class I and class II HLA molecules, and even small reductions in their expression levels leads to substantially improved outcomes.

Endothelial cells provide a good model for studying cytokine regulation of MHC expression in vitro since these cells are readily available from primary tissue and are known to function as antigen presenting cells following treatment with cytokines. Cultured human umbilical endothelial cells (HUVECs) constitutively express class I but not class II MHC (HLA) antigens under normal culture conditions. Alpha and beta interferons (IFN- $\alpha$ , IFN- $\beta$ ), as well as alpha and beta tumor necrosis factors (TNF- $\alpha$ , TNF- $\beta$ ), increase the levels of class I HLA expression in HUVECs without affecting class II HLA levels (Collins et al., 1986, Proc. Natl. Acad. Sci. USA 38: 446; Pober et al., 1987, J. Immunol. 138: 3319). Only gamma interferon (IFN- $\gamma$ ) demonstrates the capacity to upregulate both class I and II HLA expression (Geppert and Lipsky, 1985, J. Immunol. 135: 3750). Cytokine treatment of HUVECs results in increased

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levels of steady-state RNA levels for HLA antigens as well as increased cell-surface expression (Collins et al., 1986, Proc. Natl. Acad. Sci. USA 38: 446). TNF- $\alpha$  and TNF- $\beta$  act synergistically with IFN- $\gamma$  to enhance class I MHC expression without affecting IFN- $\gamma$ -mediated class II induction (Lapierre et al., 1988, J. Exp. Med. 167: 794). In contrast, neither IFN- $\alpha$  nor IFN- $\beta$  synergize with IFN- $\gamma$  to enhance class I expression, but both inhibit the IFN- $\gamma$ -mediated induction of class II expression.

## 2.2. ROLE OF ENDOTHELIUM IN FIBRINOLYSIS AND THROMBOSIS

Hemostasis of the vascular system is a function of the interactions between blood vessels, the formed elements of blood such as monocytes and platelets, and various blood coagulation proteins. Abnormalities in coagulation proteins can result in hemorrhagic and thrombolytic disorders. Thrombosis is a primary component in the pathogenesis of, for example, arteriosclerosis and coronary heart disease (Gadjusek et al., 1986, J. Cell Biol. 103: 419).

Dissolution of thrombi depends critically on the degradation of the clot component fibrin by the serine protease plasmin. Plasmin is generated from its inactive precursor, plasminogen, by two plasminogen activators: tissue-type plasminogen activator (t-PA) and urokinase-type plasminogen activator (u-PA). Vascular endothelial cells line the luminal surface of the vascular bed and secrete both t-PA and u-PA, as well as multiple molecular forms thereof (Booyse et al., 1988, J. Biol. Chem. 263: 15129), and are believed to be actively involved in the specific breakdown of locally deposited fibrin.

Plasminogen activators, plasminogen and plasmin all bind to fibrin molecules. Interestingly, t-PA but not u-PA requires fibrin as a cofactor for maximal catalytic

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efficiency, suggesting that a major physiologic function of t-PA may be the modulation of endothelial cell-mediated fibrinolysis (Camilo et al., 1971, Proc. Soc. Exp. Biol. Med. 138: 2771). Localization of fibrinolysis to the fibrin  
5 clot is further controlled by PA inhibitors (PAIs). PAI-1, the primary inhibitor found in plasma and serum, inactivates t-PA and u-PA by forming one to one complexes and plays an important role in regulating fibrinolysis (van Mourik et al., 1984, J. Biol. Chem. 259: 14914). Thus, the  
10 level of endothelial cell-mediated fibrinolytic activity expressed extracellularly represents the net balance between PAs and PAI-1.

The synthesis and release of both PA and PAI-1 by endothelial cells is regulated to some degree by hormones  
15 and cytokines. Basic fibroblast growth factor (bFGF) stimulates the expression of u-PA and t-PA in bovine capillary endothelial cells (Saksela et al., 1987, J. Cell Biol. 105: 957), an effect antagonized by transforming growth factor- $\beta$  (TGF- $\beta$ ) which inhibits PA synthesis while  
20 promoting the synthesis and secretion of PAI-1 (Laiho et al., 1987, J. Biol. Chem. 262: 17467; Saksela et al., 1987, J. Cell Biol. 105: 957). The inflammatory cytokines TNF- $\alpha$  and IL-1 have also been characterized as fibrinolytic inhibitors since they amplify the synthesis and secretion  
25 of PAI-1 (Nachman et al., 1986, J. Exp. Med. 163: 1545).

Evidence from in vitro studies show that the endothelium plays an active role in regulating thrombotic processes. Endothelium maintains an anti-thrombolytic phenotype under normal conditions and inhibits thrombus  
30 formation in vivo by four known mechanisms: inactivating thrombin, inhibiting thrombin expression, inhibiting platelet adhesion and aggregation, and fibrinolysis (reviewed in Wallis and Harlan, 1986, Pathol. Immunopathol. Res. 5: 73-103). Three thrombolytic agents are currently



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in widespread use: streptokinase, urokinase and recombinant t-PA. These agents convert circulating plasminogen to plasmin, which in turn lyses the fibrin component in thrombi. Although t-PA has certain advantages in that its action is directed to fibrin clots since it requires fibrin as a cofactor, like streptokinase and urokinase it can also solubilize hemostatic plugs where they are needed most. In the short time that it has been available to patients suffering from acute myocardial infarction, t-PA has demonstrated deleterious side effects including systemic hemorrhagic complications. Therefore, more specific and controllable means for enhancing thrombolysis is desirable.

15 2.3. ANGIOGENESIS

Angiogenesis, or neovascularization, is the process of new blood vessel formation by endothelial cells and is rare in adults under normal physiological conditions except during wound repair, ovulation, menstruation and placenta formation. The balance between naturally occurring inducers and inhibitors of angiogenesis usually resolves in favor of inhibitory influences. Angiogenesis is often associated with disease, such as diabetic retinopathy, neovascular glaucoma, rheumatoid arthritis, hemangioma and cancer (Folkman, in Thrombosis and Hemostasis 583-596, Verstraete et al., Eds., Leuven University Press 1987). Tumors produce a variety of factors which activate and attract endothelial cells (Folkman and Klagsbrun, 1987, Science 235: 442) and the vigorous angiogenesis that results is absolutely necessary for their continued growth and metastases (Folkman and Cotran, 1976, Int. Rev. Exp. Pathol. 16: 207).

Another form of life-threatening disease associated with angiogenesis is Kaposi's sarcoma (KS) which develops

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in patients suffering from infection with the human immunodeficiency virus type 1 (Friedman-Kein et al., 1982, Ann. Int. Med. 96: 693) and in patients receiving immunosuppressive therapy (Greenfield et al., 1986, J. Rhematol. 13: 637). KS lesions are characterized by a highly vascularized hemorrhagic histological pattern. The tumor is believed to be of endothelial origin (Macher, 1988, Public Health Report 103: 246). KS cells isolated from patients with Acquired Immune Deficiency Disease (AIDS) produced strong angiogenic reactions in mice, resulting in characteristic KS lesions (Salahuddin et al., 1988, Science 242: 430). KS cells also secrete factors which have mitogenic effects on cultured endothelial cells. The therapeutic benefit of compounds which control pathologic angiogenesis in such diseases has led to a search for effective inhibitors of neovascularization.

A number of compounds which inhibit neovascularization have been identified such as anti-inflammatory agents (Polverini and Novak, 1986, Biochem. Biophys. Res. Comm. 140: 90), angiostatic steroids (Ingber et al., 1986, Endocrinol. 119: 1768), placental RNase inhibitor (Shapiro and Vallee, 1987, Proc. Natl. Acad. Sci. USA 84: 2238), as well as a variety of compounds which influence matrix synthesis and integrity (Ingber and Folkman, 1988, Lab. Invest. 59: 44). Certain cytokines also demonstrate angiostatic activities including IFN- $\gamma$ , TNF- $\alpha$  and TGF- $\beta$ , all of which have been shown to block the proliferative response of cultured endothelial cells to basic fibroblast growth factor (bFGF), a potent angiogenic promoter (Bolen et al., in Current Communications in Molecular Biology, 119-124, Rifkin and Klagsbrun, Eds., Cold Spring Harbor Press 1987). However, when these cytokines were tested in rabbit corneal neovascularization assays, they exhibited angiogenic activity, a response thought to result from the

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chemotactic effects of these cytokines on inflammatory leukocytes involved in the release of angiogenic factors (Freter-Schroder et al., 1987, Proc. Natl. Acad. Sci. USA 84: 527). Another cytokine, interleukin-1 (IL-1) also  
5 demonstrates angiogenic properties in the rabbit eye anterior chamber model, initiating inflammatory response as well as leukocyte infiltration (Dinarello, 1989, in Advances in Immunology 44: 153, Academic Press).

Tumor-induced angiogenesis can be demonstrated by  
10 placing malignant tumor tissue into the rabbit cornea in which vaso-proliferation originates from the limbal vessels and migrates towards the tumor graft. Chakravarti and Maitra found that vaso-proliferation could be inhibited in this model by placing a piece of mesenteric lymph node  
15 containing activated lymphocytes along with the tumor graft (Chakravarti and Maitra, 1983, Experientia 39: 542). It is possible that Oncostatin M, a natural product of T cells, is involved in the inhibition observed in that study.

20        2.4    EXPRESSION OF INTERLEUKIN-6 IN ENDOTHELIAL  
             CELLS AND RELATIONSHIP TO IMMUNE RESPONSE  
             AND ANGIOGENESIS

Although interleukin 6 (IL-6) was identified more than nine years ago, its functional multiplicity has only  
25 recently been appreciated. IL-6 occupies a prominent position in the cytokine networks regulating cell growth, development of the hematopoietic and immune systems, and host responses to infection and injury (reviewed by Sehgal et al., 1987, Science 235:731). For example, IL-6 is  
30 capable of promoting T and B lymphocyte growth and differentiation (Garman et al. 1987, Proc. Natl. Acad. Sci. USA., 84:769; Takai et al, 1988, J. Immunol. 140:508). Additionally, IL-6 has been reported to inhibit the proliferation of human endothelial cells (May et al., 1989,

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Biochem, Biophys, Res. Comm., 159:991) and thereby would be expected to antagonize the angiogenic process.

### 3. SUMMARY OF THE INVENTION

5       The use of Oncostatin M to control endothelial cell immunogenicity, fibrinolytic activity, proliferation and cytokine synthesis is described. Oncostatin M purified from natural sources, recombinant Oncostatin M, or Oncostatin M prepared by chemical synthetic techniques may  
10       be used. The invention is described by way of examples in which the various effects of Oncostatin M on several cell types are determined using in vitro assays.

          The invention is subdivided for the purpose of description according to the different areas of therapeutic  
15       utility it encompasses. First, the invention is directed to the use of Oncostatin M to mitigate endothelial tissue immunogenicity, the primary element involved in the rejection of allografted organs and the progression of certain autoimmune diseases. This aspect of the invention  
20       is described by way of examples in which the ability of Oncostatin M to inhibit the expression of MHC antigens on the surface of human endothelial cells in vitro is demonstrated. Oncostatin M is capable of substantially antagonizing IFN- $\gamma$  and TNF- $\alpha$  stimulated expression of class  
25       I and class II HLA antigens and appears to be specific for action on endothelial cells. Second, the invention is directed to the use of Oncostatin M to induce and/or maintain the fibrinolytic phenotype in vascular endothelium, a state of affairs vital to sustaining normal  
30       functioning of the vascular system. This aspect of the invention is described by way of examples in which the ability of Oncostatin M to stimulate vascular endothelial cell plasminogen activator activity, resulting in increased levels of bioactive plasmin, is demonstrated. Applicants  
35       show that Oncostatin M specifically induces the expression

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of active plasminogen activator molecules and/or inhibits the expression and/or function of plasminogen activator inhibitors. Third, the invention is directed to the use of Oncostatin M to inhibit the process of angiogenesis, a prominent component in the pathology of many life-threatening diseases including cancer. This aspect of the invention is described by way of examples in which the ability of Oncostatin M to inhibit endothelial cell proliferation in response to mitogenic stimulation by angiogenic factors is demonstrated. Fourth, the invention is directed to the use of Oncostatin M to induce the synthesis of the pleiotypic cytokine interleukin-6 in endothelial cells. This aspect of the invention is described by way of examples in which the amplification of IL-6 mRNA and protein in human endothelial cells treated with Oncostatin M is described. The effects of Oncostatin M on endothelial cell morphology, leukocyte adherence and leukocyte chemotaxis are also described.

#### 4. DESCRIPTION OF THE FIGURES

FIG. 1. Synergistic inhibitory effects of Oncostatin M and TGF- $\beta$  on endothelial cell HLA antigen expression induced by IFN- $\gamma$ . Oncostatin M ( ); TGF- $\beta$  ( ); Oncostatin M plus TGF- $\beta$  ( ). A: Effects on class I HLA antigen expression. B: Effects on class II HLA-DR antigen expression.

FIG. 2. Oncostatin M receptor binding on HUVECs: saturation curve, scatchard plot and SDS-PAGE autoradiograph (inset). Data obtained and compiled as described in Section 6.2.4., infra.

FIG. 3. Specificity of Oncostatin M action for induction of PA activity on endothelial cells. BAECs were treated for 72 hours with 10 nM recombinant Oncostatin M (Malik et al., 1989, Mol. Cell. Biol., in press),

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recombinant TNF- $\alpha$  (AmGen) and recombinant TGF- $\beta$  (Gentry et al., 1987, Mol. Cell. Biol. 7: 3418-3427). Cell-associated PA activity was determined as described in Section 7.1.2., infra.

5        FIG. 4.    Effective dose range for Oncostatin M stimulation of endothelial cell PA activity. BAECs were treated with varying concentrations of (A) native Oncostatin M (Zarling et al., 1986, Proc. Natl. Acad. Sci. USA 38: 9739-9743) and (B) recombinant Oncostatin M. Cell-associated activity was determined as described in Section 10    7.1.2., infra.

15        FIG. 5.    Oncostatin M receptor binding saturation curve. The amount of Oncostatin M bound to BAECs is plotted against the amount applied demonstrating the saturable nature of Oncostatin M receptors on BAECs. Binding conditions were as described in Section 7.1.3., infra.

20        FIG. 6.    Scatchard plot of BAEC Oncostatin M receptor binding data. Binding conditions were as described in Section 7.1.3., infra. Plot was analyzed as described in Section 7.2.2., infra.

25        FIG. 7.    Inhibition of endothelial cell growth by Oncostatin M. BAECs were grown to confluence in 24-well tissue culture plates with minimal essential media, MEM/F-10 (1:1), supplemented with 10% FBS (Hyclone). Serum-containing media was removed and monolayers washed twice with Dulbecco's PBS and replaced with fresh serum-free MEM/F-10. Triplicate wells were treated with varying doses of Oncostatin M alone (\*) or in combination with 5 30 ng/ml bFGF (o). Following 3-day incubation at 37 degrees C, cell number was determined by hemacytometer counts. The difference in cell number at zero concentration Oncostatin M indicates the mitogenic response of these cells to bFGF.

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FIG. 8. Inhibition of bovine aortic endothelial cell growth by Oncostatin M. The growth inhibitory effect of Oncostatin M was quantified as described in Section 8.1., *infra*. The decrease in cell number resulting from Oncostatin M treatment is plotted as percent growth inhibition (number of untreated cells/well - number of treated cells/well divided by the number of untreated cells/well X 100).

FIG. 9. Inhibition of bFGF-induced growth of fetal bovine heart endothelial cells as determined by the inhibition of DNA synthesis assay described in Section 8.1., *infra*. The decrease in incorporated radioactivity due to Oncostatin M treatment is plotted as percent growth inhibition (CPMs of untreated cells - CPMs of treated cells divided by CPMs of untreated cells X 100).

FIG. 10. Photomicrographs of untreated BAECs (Panel A) and BAECs treated with Oncostatin M (Panel B) demonstrating the morphological effects of Oncostatin M on BAECs. Cell monolayers were examined for morphological alterations after 48 hours exposure to 400 pM Oncostatin M. Photomicrographs were taken at 250X magnification.

FIG. 11. Stimulation of leukocyte adhesion to bovine aortic endothelial cells by Oncostatin M treatment. Cells were treated as described in Section 9.2., *infra*. Lymphoblast binding was quantitated by averaging the number of cells observed in five randomly selected high power fields. The filled bars represent adhesion of lymphoblasts to untreated cells; crosshatched bars represent adhesion to Oncostatin M treated cells.

FIG. 12. Time-dependent release of IL-6 from stimulated human umbilical vein endothelial cells. Confluent cultures were treated with ( ) and without ( ) 100 ng/ml Oncostatin M. Triplicate 200 µl aliquots of conditioned media were withdrawn at the indicated time

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intervals and the concentration of IL-6 determined by ELISA, as described in Section 10.1.3., *infra* (expressed in ng/ml). The standard error in these assays was 2%.

FIG. 13. Dose-dependent release of IL-6 from  
5 stimulated human umbilical vein endothelial cells. Confluent cultures were treated with varying doses of recombinant Oncostatin M for 72 hours. Triplicate 200  $\mu$ l aliquots of conditioned media were withdrawn and the concentration of IL-6 determined by ELISA. The amount of  
10 IL-6 released in ng was normalized for  $10^6$  cells.

FIG. 14. Expression of IL-6 mRNA transcripts in stimulated human umbilical vein endothelial cells. Cells were exposed to 100 ng/ml recombinant Oncostatin M for 6 hours. Then 5 ng total cellular RNA were analyzed by  
15 Northern blot as described in Section 10.1.4., *infra*. Lane 1: positive control RNA; Lane 2: untreated HUVEC RNA; Lane 3: Oncostatin M-treated HUVEC RNA.

#### 5. DETAILED DESCRIPTION OF THE INVENTION

20 The present invention is directed to methods for controlling endothelial cell proliferation and effector functions and to methods for the treatment of human vascular, immune and cell-growth disorders using Oncostatin M. The invention is based in part on the discovery that  
25 Oncostatin M mediates various biological effects on endothelial cells. The invention is described by way of examples in which the various biological effects of Oncostatin M on mammalian cells are determined using *in vitro* assay systems. The clinical implications of the  
30 biological effects mediated by Oncostatin M revealed and described herein may encompass a wide range of therapeutic uses of Oncostatin M pertaining to human vascular medicine, immunology, and cancer, and any such uses not specifically



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described or suggested herein are within the scope of the invention.

Oncostatin M, originally identified for its inhibitory effects on human tumor cell lines, was first isolated from  
5 phorbol 12-myristate 13-acetate (PMA)-induced human histiocytic lymphoma cells (Zarling et al., 1986, Proc. Natl. Acad. Sci. USA 83: 9739-9743) and from activated T lymphocytes (Brown et al., 1987, J. Immunol. 139: 2977-2983). The molecule is a heat and acid stable protein  
10 comprised of a single polypeptide chain of  $M_r = 28,000$ . Like other naturally occurring growth regulators, Oncostatin M exhibits a variety of biological activities. Growth inhibition is observed with some, but not all, human tumor cell lines. In contrast, the growth of some normal  
15 fibroblasts, such as human foreskin fibroblasts or WI-38 cells, is stimulated by exposure to Oncostatin M (Zarling et al., 1986, Proc. Natl. Acad. Sci. USA 83: 9739-9743). The gene for Oncostatin M has been cloned and sequenced, and an active form of recombinant Oncostatin M has recently  
20 been expressed in mammalian cells (Copending application Serial No.144,574 filed January 15, 1988, which is incorporated herein by reference in its entirety). The mature form, after cleavage of the signal peptide, is a glycoprotein containing 228 amino acids, five of which are  
25 cysteine residues. The protein has an extremely hydrophilic carboxy terminal domain. Although Oncostatin M is not structurally related to other known cytokines, its mRNA contains an AU-rich region at its 3' untranslated end. This region in the Oncostatin M message is homologous to  
30 that of many cytokines, lymphokines and other growth-regulatory molecules, suggesting a common mode of regulating gene expression. A cellular receptor for Oncostatin M has been found on a variety of mammalian cells. The major Oncostatin M receptor molecule is a

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specific protein of Mr = 150,000-160,000 (Linsley et al, 1989, J. Biol. Chem. 264: 6528-6532).

In accordance with the invention, Oncostatin M may be obtained by techniques well known in the art from a variety of cell sources which synthesize bioactive Oncostatin M including, for example, cells which naturally produce Oncostatin M and cells transfected with recombinant DNA molecules capable of directing the synthesis and/or secretion of Oncostatin M. Alternatively, Oncostatin M may be synthesized by chemical synthetic methods including but not limited to solid phase peptide synthesis. Methods for the production of Oncostatin M are described in copending application Serial No. 144,574 filed January 15, 1988, a continuation-in-part of application Serial No. 046, 846 filed May 4, 1987, a continuation-in-part of application Serial No. 935,283 filed November 26, 1986, a continuation-in-part of application Serial No. 811,235 filed December 20, 1985, each of which is incorporated by reference herein in its entirety.

In the practice of the method of the invention, the use of Oncostatin M obtained by any method, as well as the use of modified or truncated Oncostatin molecules and Oncostatin M analogs which retain the desired activity, are within the scope of the invention. In this regard, variations in the Oncostatin M primary structure, as well as variations in higher levels of structural organization, the type of covalent bonds linking the amino acid residues, and/or addition of groups to the terminal residues of Oncostatin M are within the scope of the invention. For example, the Oncostatin M molecule used in accordance with the invention may include conservative or non-conservative alterations in the amino acid sequence which result in silent changes that preserve the functionality of the molecule including, for example, deletions, additions and

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substitutions. Such altered Oncostatin M molecules may be desirable where they provide certain advantages in their use. As used herein, conservative substitutions would involve the substitution of one or more amino acids within  
5 the sequence of Oncostatin M with another amino acid having similar polarity and hydrophobicity/hydrophilicity characteristics resulting in a functionally equivalent molecule. Such conservative substitutions include but are not limited to substitutions within the following groups of  
10 amino acids: glycine, alanine; valine, isoleucine, leucine; aspartic acid, glutamic acid; asparagine, glutamine; serine, threonine; lysine, arginine; phenylalanine, tyrosine; and methionine, norleucine.

In another embodiment of the invention, Oncostatin M  
15 may be linked to carrier molecules. For example, Oncostatin M could be covalently coupled to an antibody molecule specific for endothelial cells or for some other cell surface antigen which will allow Oncostatin M to be targeted to cells which express that particular antigen.  
20 Similarly, Oncostatin M may be linked to other "targeting" molecules such as hormones, growth factors, cytokines, etc. In this way, the Oncostatin M molecule could be altered so that it is taken up by cells that may not express a receptor for the particular Oncostatin M molecule chosen  
25 for use. Such coupling techniques are well known in the art and can include, for example, the use of cross-linking agents, schiff-base formation, amide bonds, peptide bonds, sulfide bonds, etc.

To facilitate description, the present invention may  
30 be broadly classified with respect to its major aspects; specifically, the use of Oncostatin M to (1) modulate immunity, (2) enhance plasminogen activator and fibrinolytic activity, and (3) control angiogenesis. These divisions are made solely for the purpose of description

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and are in no way intended to limit or restrict the scope of the specification or the appended claims.

#### 5.1. ONCOSTATIN M AS AN IMMUNOMODULATOR

5 One aspect of the present invention relates to the use of Oncostatin M as an immunomodulator in the treatment of human autoimmune and alloimmune diseases. In this regard, applicants have discovered through a series of experiments such as those described in Section 6., et seq.  
10 that Oncostatin M is capable of inhibiting the expression of class I and II HLA antigens on the surface of human endothelial cells in vitro. Therefore, Oncostatin M may find use in decreasing the immunogenicity of endothelial tissue to helper and/or effector T lymphocytes.

15

##### 5.1.1. USE OF ONCOSTATIN M IN ORGAN TRANSPLANTATION

Since class I molecules appear to be the initial target for cytotoxic T lymphocytes, depression in class I expression would be expected to prevent or inhibit the  
20 onset of strong secondary responses. Perhaps more importantly, the inhibition of class II expression on endothelial cells may block the recruitment of antigen-specific, gamma-interferon-secreting helper T lymphocytes, thus thwarting the development of immune response. In a  
25 particular embodiment of the invention, compounds containing effective doses of Oncostatin M formulated in suitable pharmacological carriers may be administered to organ transplant recipients such as kidney, heart and lung transplant recipients, via any appropriate route including  
30 but not limited to local or systemic injection, in order to inhibit or prevent the expression of HLA antigens and rejection of the transplant. In addition, Oncostatin M may be linked to a carrier or targeting molecule and/or incorporated into liposomes, microcapsules, and controlled

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release preparations prior to administration in vivo.

Through a series of experiments, such as those described in Section 6, infra, applicants have determined that

endothelial cell expression of class I and II MHC antigens, particularly gamma-interferon- and tumor necrosis factor-alpha-stimulated expression, is specifically antagonized by Oncostatin M at concentrations ranging from 1-50 ng/ml.

For example, at a concentration of 5 ng/ml, Oncostatin M inhibited IFN- $\gamma$ -stimulated class I antigen expression by

51% and TNF- $\alpha$ -stimulated expression by a striking 141%.

Induction of class II antigen expression by IFN- $\gamma$  was inhibited by as much as 84%. When used in combination with a synergistic cytokine such as TGF- $\beta$ , low concentrations of Oncostatin M were effective in producing strong inhibitory

effects. In addition, applicants' research data suggests that Oncostatin M is incapable of inhibiting class I or class II HLA antigen expression on cells of the

monocyte/macrophage lineage. Use of Oncostatin M may therefore offer a better alternative to Cyclosporin A. The broad effects of Cyclosporin A, currently the principal immunosuppressive agent used in allograft transplantations, results from the inhibition of T lymphocyte proliferation generally. Oncostatin M does not have a similar effect on T cell proliferation.

In accordance with this aspect of the invention, Oncostatin M may be used alone or in combination with one or more other cytokines, growth factors or immunosuppressive agents including but not limited to TGF- $\beta$ , Cyclosporin A and corticosteroids in order to increase the likelihood of a transplant recipient's acceptance of the donor organ. Applicants have in this regard observed that TGF- $\beta$  acts synergistically with Oncostatin M to strongly inhibit the expression of HLA antigens on IFN- $\gamma$ -stimulated endothelial cells. As little as 50 pg/ml

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Oncostatin M in combination with 0.5 ng/ml TGF- $\beta$  resulted in a nearly 50% reduction of class I antigen expression (Section 6.2.2., *infra*). Furthermore, the expression of IFN- $\gamma$ -stimulated class II antigens was inhibited 80% by the combination of 0.5 ng/ml Oncostatin M and 1 ng/ml TGF- $\beta$ .

5.1.2. USE OF ONCOSTATIN M TO INDUCE THE SYNTHESIS AND SECRETION OF CYTOKINES FROM ENDOTHELIAL CELLS

Applicants have determined that Oncostatin M is capable of inducing endothelial cells to synthesize and secrete bioactive cytokines, including, at least, interleukin-6 and GM-CSF. The effect of Oncostatin M on interleukin-6 synthesis and secretion from human endothelial cells is both time and dose dependent. As described more fully in Section 10, *infra*, cultured human umbilical vein endothelial cells treated with Oncostatin M respond rapidly by secreting increased levels of bioactive interleukin-6 (IL-6). In addition, applicants have determined that this effect is induced at the transcriptional level since Oncostatin M treated endothelial cells exhibit increased levels of IL-6 specific mRNA. Therefore, Oncostatin M may be used as an IL-6 inducing agent on human endothelial cells where the increased production of IL-6 is desired. IL-6 synthesis and secretion may be induced systemically by the introduction of Oncostatin M to the circulatory system or may be targeted to specific tissues using techniques known in the art, including but not limited to topical administration, injection, or through the use of target specific compounds directly linked to Oncostatin M.

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5.2. USE OF ONCOSTATIN M TO INDUCE A  
FIBRINOLYTIC PHENOTYPE IN VASCULAR ENDOTHELIUM

Another aspect of the invention is directed to the use  
5 of Oncostatin M to shift and/or maintain the balance  
between the constitutive antithrombogenic and the inducible  
procoagulant phenotypes of endothelium in favor of the  
antithrombogenic phenotype. The results described in  
Section 7, infra indicate that Oncostatin M dramatically  
10 and specifically stimulates the expression of PA activity  
in endothelial cells in vitro, resulting in elevated levels  
of bioactive plasmin. These findings suggest that  
Oncostatin M may be useful in inducing increased  
endothelial cell-mediated fibrinolysis.

15 It is known that endothelial cells generally inhibit  
thrombus formation, and that this effect is mediated by  
four different pathways, one of which is fibrinolysis.  
Endothelial cells are actively involved in fibrinolysis  
through the release of plasminogen activators. Oncostatin  
20 M may therefore be useful in the treatment of thrombotic  
cardiovascular diseases. For example, patients treated for  
acute myocardial infarction (AMI) with urokinase,  
streptokinase, or t-PA may benefit from concurrent and/or  
sustained treatment with Oncostatin M in order to reduce  
25 the likelihood of recurrent thrombi. Also, the ability of  
Oncostatin M to shift the endothelial surface to a more  
fibrinolytic phenotype may be useful in the treatment of a  
variety of other Disseminated Intravascular Coagulation  
(DIC) syndromes such as deep vein thrombosis, pulmonary  
30 embolism, peripheral arterial thromboembolism, hemolytic  
uremic syndrome and thrombotic thrombocytopenic purpura.  
Effective doses of Oncostatin M formulated in suitable  
pharmacological carriers may be administered in vivo via  
any appropriate route including but not limited to  
35 injection, infusion and selective catheterization. In

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addition, Oncostatin M may be linked to a carrier or targeting molecule and/or incorporated into liposomes, microcapsules, and controlled release preparations prior to administration in vivo.

5       The ability of Oncostatin compositions to stimulate PA, leading to fibrinolysis or other important foci of PA activity, can readily be tested using in vitro assay systems such as the PA activity assay described in Section 7 et seq. herein. The functional equivalence and/or  
10   increased efficacy of modified Oncostatin M molecules or Oncostatin M analogs may be evaluated similarly. In addition to testing the effects of Oncostatin M compounds on endothelial cells, other cell types may be assayed for their responsiveness to the PA activity-inducing property  
15   of Oncostatin M.

### 5.3. USE OF ONCOSTATIN M TO CONTROL ANGIOGENESIS

Yet another aspect of the invention is directed to the use of Oncostatin M to inhibit neovascularization in  
20   pathological angiogenic conditions including but not limited to cancer. Applicants believe that Oncostatin M compounds may strongly inhibit neovascularization in such conditions based on results from in vitro studies, such as those described in Section 8., infra, demonstrating that  
25   Oncostatin M blocks the response of endothelial cells to proliferative stimuli (i.e., bFGF). Moreover, unlike other cytokines which inhibit angiogenesis, Oncostatin M is not chemotactic for monocyte-macrophages (Section 9., infra) and therefore is not likely to initiate angiogenesis in  
30   vivo via secondary effects on leukocyte recruitment.

Oncostatin M may be useful in the treatment of Kaposi's sarcoma (KS). KS appears to be derived from endothelial cells (Jones et al., 1986, J. Clin. Pathol. 39: 742; Macher, 1988, Public Health Report 103: 246) and may



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therefore be susceptible to the anti-proliferative effects of Oncostatin M. Similarly, Oncostatin M may also be useful in the treatment of many other diseases associated with angiogenesis including, for example, diabetic

5 retinopathy, glaucoma, hemangioma and various cancers. In a specific embodiment of the invention, compounds containing effective doses of Oncostatin M formulated in suitable pharmacological carriers may be administered to patients suffering from diseases associated with

10 angiogenesis via any appropriate route including but not limited to injection, topical application, etc., in order to inhibit neovascularization and the progression of the disease. In addition, Oncostatin M may be linked to a carrier or targeting molecule and/or incorporated into

15 liposomes, microcapsules, and controlled release preparations prior to administration in vivo. The ability of Oncostatin M compositions to inhibit neovascularization may be assessed using in vitro assay systems such as the growth inhibitory and chemotactic assays described in

20 Section 8 et seq. herein. The functional equivalence and/or increased efficacy of modified Oncostatin M molecules or Oncostatin M analogs may be evaluated similarly.

25 6. EXAMPLE: MODULATION OF ENDOTHELIAL CELL HLA ANTIGEN EXPRESSION BY ONCOSTATIN M IN VITRO

The in vitro experiments described below demonstrate, inter alia, that Oncostatin M inhibits the cytokine-stimulated expression of class I and class II HLA antigens

30 on human endothelial cells, but not on monocyte-macrophages, and that TGF- $\beta$  synergizes with Oncostatin M to produce this inhibitory effect.

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## 6.1. MATERIALS AND METHODS

### 6.1.1. ENDOTHELIAL CELL CULTURES

Human umbilical vein endothelial cells (HUVECs) were  
5 isolated from umbilical vein as described (Wall et al.,  
1978, J. Cell. Physiol. 96: 203). Cells were passaged with  
collagenase and grown to confluence on gelatin-coated  
plasticware in CS-1 defined serum free medium (Cell  
Systems, Kirkland, WA) substituted with 50 µg/ml heparin  
10 and recombinant ECGS (Bionetics). Cells were given fresh  
unsupplemented media at least 12 hours prior to  
experimentation.

### 6.1.2. IMMUNOSTAINING

15 Several fluorescein-labeled monoclonal antibodies  
(MAbs) were employed for the detection of class I and  
class II HLA antigens: H1DE (Gladstone et al.,  
Histocompatibility Testing, 429, Dupont, Ed., 1984) was  
used for the detection of class I HLA antigens; a DR-  
20 specific antibody, VI.15 (Gladstone et al., 1982, Proc.  
Natl. Acad. Sci. USA 79: 1235), was used for the detection  
of class II HLA-DR antigen; antibody 33.1 was used for the  
detection of HLA-DQ antigens and was provided by G. Marti  
(Marti et al., 1983, J. Exp. Med. 158: 1924-1983); HB10a  
25 was used for the detection of class II HLA-DR and HLA-DP  
antigens and was provided by Dr. E. Clark (Regional Primate  
Research Center at Washington University, Seattle, WA).

### 6.1.3. QUANTITATIVE ANTIGEN ASSAY

30 The expression of cell surface HLA antigens was  
measured essentially as described (Gladstone et al., 1982,  
Proc. Natl. Acad. Sci. USA 79: 1235-39) with modifications  
for fluorescent activated cell sorter (FACS) analysis  
(Basham and Merigan, 1983, J. Immunol. 130: 1492).

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Briefly,  $5 \times 10^4$  cells per sample were immunostained and HLA antigen expression quantified by indirect immunofluorescence using a FACS analyzer. MAbs were incubated for 45 minutes in each step. Sample populations were compared by mean channel fluorescence on a four decade logarithmic scale and, where appropriate, linear fluorescence equivalents were obtained by conversion.

#### 6.1.4. CYTOKINES

Recombinant Oncostatin M was prepared as described (Malik et al., 1989, Mol. Cell. Biol., in press), recombinant TGF- $\beta$  as described in Gentry et al., 1987, Mol. Cell. Biol. 7: 3418), recombinant IFN- $\gamma$  and TNF- $\alpha$  were purchased from Amgen Inc. Natural Oncostatin M was prepared as described in (Zarling et al., 1986, Proc. Natl. Acad. Sci. USA 83: 9737).

#### 6.1.5. ONCOSTATIN M RECEPTOR ASSAY

Highly purified human recombinant Oncostatin M was radiolabeled by the IODO-GEN procedure (Fraker and Speck, 1978, Biochem. Biophys. Res. Comm. 80: 849) to a specific activity of 52  $\mu\text{Ci}/\mu\text{g}$ . Radioreceptor assays were conducted in situ on confluent monolayers of HUVECs grown in 24-well tissue culture plates ( $10^5$  cells/well) in duplicate. Monolayers were first washed twice with binding buffer (Dulbecco's MEM + 0.1% bovine serum albumin + 15 mM HEPES) and then 250  $\mu\text{l}$  binding buffer containing 1 ng/ml radiolabeled Oncostatin M and variable amounts of unlabeled Oncostatin M were added to the monolayers. Cells were incubated at 23 degrees C for 3 hours to maintain steady state binding (Linsley et al., 1988, J. Biol. Chem. 263: 4282). Following the incubation period, cells were washed with cold binding buffer and solubilized in 1N NaOH. Radioactivity was detected by a gamma spectrophotometer and

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data plotted according to the method of Scatchard (Scatchard, 1949, Ann. N.Y. Acad. Sci. 51: 660). Non-specific binding was measured in the presence of a 400-fold molar excess of unlabeled Oncostatin M.

5

## 6.2. RESULTS

### 6.2.1. ONCOSTATIN M INHIBITS CYTOKINE-STIMULATED HLA ANTIGEN EXPRESSION ON HUMAN ENDOTHELIAL CELLS

10       The capacity of Oncostatin M to modulate the regulation of HUVEC MHC antigen expression by other cytokines was evaluated by indirect immunofluorescence and FACS quantitation as described in Materials and Methods, supra. Table I presents the effects of various cytokines  
15       on HUVEC HLA antigen expression. At a concentration of 100U/ml; both IFN- $\gamma$  and TNF- $\alpha$  significantly affected the expression of class I antigen, amplifying expression by fivefold and twofold respectively. Additionally, IFN- $\gamma$   
20       amplified class II antigen expression by greater than sixfold. In contrast, neither TGF- $\beta$  nor Oncostatin M were able to amplify class I or class II expression.

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TABLE I<sup>1</sup>EFFECTS OF VARIOUS CYTOKINES ON HUVEC HLA ANTIGEN  
EXPRESSION

| CYTOKINE        | H9<br>(control IgG) | CLASS I<br>(HLA-A,B,C) | CLASS II<br>(HLA-DR,DP) |
|-----------------|---------------------|------------------------|-------------------------|
| None            | 2.3                 | 39                     | 2.9                     |
| IFN-G, 100U/ml  | 2.4                 | 200                    | 18.6                    |
| TNF-a, 100U/ml  | 2.6                 | 91                     | 3.7                     |
| TGF-B, 50ng/ml  | 2.4                 | 37                     | 2.7                     |
| Onco M, 50ng/ml | 2.4                 | 29                     | 3.1                     |

<sup>1</sup> Values expressed in linear fluorescence equivalents

Table II presents the effects of different concentrations of Oncostatin M on the cytokine-induced expression of class I and class II antigens. Oncostatin M antagonized IFN- $\gamma$ - and TNF- $\alpha$ -stimulated HLA antigen expression in a dose dependent manner. At a concentration of 5 ng/ml, Oncostatin M inhibited IFN- $\gamma$ -stimulated class I HLA-A,B,C antigen expression by 51% and TNF- $\alpha$ -stimulated expression by 141%. Induction of class II HLA-DR and HLA-DQ antigens by IFN- $\gamma$  was inhibited 84% and 72%, respectively, with 50 ng/ml Oncostatin M. These results strongly indicate that Oncostatin M may be useful in down-modulating the immunogenicity of endothelial cells in vivo.

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TABLE II<sup>1</sup>EFFECTS OF ONCOSTATIN M ON CYTOKINE-INDUCED  
HLA ANTIGEN EXPRESSION

| CYTOKINE                | HLA ANTIGEN EXPRESSION |                      |                      |
|-------------------------|------------------------|----------------------|----------------------|
|                         | CLASS I<br>(HLA-A,B,C) | CLASS II<br>(HLA-DR) | CLASS II<br>(HLA-DQ) |
| None                    | 30                     | 2                    | 3                    |
| IFN- $\gamma$ , 100U/ml | 113                    | 21                   | 3                    |
| +Onco M, 0.05ng/ml      | 119                    | 19                   | -                    |
| +Onco M, 0.5ng/ml       | 80                     | 11                   | -                    |
| +Onco M, 5.0ng/ml       | 17                     | 7                    | -                    |
| +Onco M, 50.0ng/ml      | -                      | 5                    | 8                    |
| None                    | 71                     |                      |                      |
| TNF- $\alpha$ , 100U/ml | 125                    |                      |                      |
| +Onco M, 0.05ng/ml      | 125                    |                      |                      |
| +Onco M, 0.5ng/ml       | 76                     |                      |                      |
| +Onco M 5.0ng/ml        | 49                     |                      |                      |

<sup>1</sup> Values expressed in linear fluorescent equivalents6.2.2. SYNERGISTIC ACTION OF ONCOSTATIN M AND TGF- $\beta$ 

The effects of Oncostatin M, TGF- $\beta$ , and Oncostatin M/TGF- $\beta$  on IFN- $\gamma$ -treated endothelial cells were evaluated and compared in order to determine whether synergistic action between TGF- $\beta$  and Oncostatin M exists. The results of these experiments are illustrated in FIG. 1. TGF- $\beta$  alone demonstrates a weak capacity for inhibiting IFN- $\gamma$ -stimulated expression of either class I HLA-A,B,C or class II HLA-DR antigens. However, suboptimal amounts of Oncostatin M in combination with TGF- $\beta$  resulted in synergistic antagonism of class I and class II antigen

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expression. For example, 50 pg/ml Oncostatin M and 0.5 ng/ml TGF- $\beta$  in combination resulted in a 49% inhibition of class I antigen expression whereas independent treatment with the same concentration of Oncostatin M or TGF- $\beta$  resulted in 7% and 15% inhibition respectively (FIG. 1A). Similarly, the combination of 0.5 ng/ml Oncostatin M and 1 ng/ml TGF- $\beta$  resulted in an 80% inhibition of class II HLA-DR expression whereas independent treatments at these concentrations resulted in 13% (Oncostatin M) and 26% (TGF- $\beta$ ) inhibitions (FIG. 1B). Therefore, with respect to the inhibition of both class I and class II antigen expression, a synergistic effect some two times greater than the predicted additive effect was observed, suggesting compositions containing both TGF- $\beta$  and Oncostatin M may be particularly useful.

#### 6.2.3. TISSUE SPECIFICITY OF ONCOSTATIN M EFFECT ON HLA EXPRESSION

In order to explore whether the inhibitory effect of Oncostatin M on HLA antigen expression is specific for endothelial cells, the capacity of Oncostatin M to antagonize the expression of cytokine-induced class II MHC antigen expression on monocytes and macrophage-like cells was determined.

Human monocytes were isolated from blood using Ficoll gradients and adhered to plastic culture dishes. Cells were assayed for class II antigen as described in Materials and Methods. Cells were treated with 100 and 250 U/ml IFN- $\gamma$  to boost basal levels of class II HLA antigens and parallel cultures were also treated with 5 ng/ml Oncostatin M. After a 3 day incubation, cells were stained with fluorescein-labeled antibodies and analyzed by indirect immunofluorescence and FACS quantitation as described in Materials and Methods, supra. The results indicate that

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Oncostatin M has no effect on either the basal or cytokine-induced levels of class II HLA antigen expression.

In another experiment, the effects of 1-10 ng/ml recombinant Oncostatin M on class II MHC antigen expression in a murine macrophage-like cell line (Wehi-3 cells) were investigated similarly. Class II antigen expression is strongly induced by either IFN- $\gamma$  or TNF- $\alpha$  in these cells (Chang and Lee, 1968, J. Immunol. 137: 2853). Similarly, in the case of human monocytes, Oncostatin M had no effect on the basal or cytokine-induced levels of class II HLA antigen expression in these cells.

Since these results suggest that Oncostatin M is incapable of inhibiting class II HLA antigen expression on cells of the monocyte/macrophage lineage, Oncostatin M may offer a therapeutically more specific alternative to the broad immunosuppressive effects induced by other compounds such as Cyclosporin A, corticosteroids, and cyclophosphamides.

#### 6.2.4. HIGH LEVEL EXPRESSION OF ONCOSTATIN M RECEPTORS ON HUVECs

HUVECs were grown to confluence in 24-well tissue culture dishes and radioreceptor assays conducted as described in Section 6.1.5., *supra*. FIG. 2 presents the saturation curve and Scatchard plot (inset) for Oncostatin M binding to HUVECs. Binding is saturable and the Scatchard plot shows a curvilinear isotherm indicating the presence of at least two classes of cell-surface binding sites on HUVECs (similar results were obtained with bovine endothelial cells, Section 7.2.2., *infra*). When analyzed by the two site model, a total concentration of 380,000 Oncostatin M receptor binding sites per cell were calculated, comprising 1,700 high affinity sites ( $K_d=5.6$  pM) and 378,300 low affinity sites ( $K_d=8.5$  nM). Half-maximal receptor occupancy occurred at 2 ng/ml (67 pM).



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which correlates with the ED<sub>50</sub> of Oncostatin M inhibition of cytokine-induced HLA antigen expression (Section 6.2.1., supra). These human endothelial cells appear to express approximately ten times more Oncostatin M receptors than  
5 bovine endothelial cells (Section 7.2.2., infra).

The Oncostatin M receptor on HUVECs was further characterized by chemically cross-linking [<sup>125</sup>I]-Oncostatin M to its receptor and analyzing the structural properties of the complex by polyacrylamide gel electrophoresis as  
10 described (Linsley et al., 1989, J. Biol. Chem. 264: 4282-4289). As shown in the autoradiograph in FIG. 2, cross-linked ligand-receptor complex migrated on a 6% SDS-PAGE under reducing conditions as a prominent 180,000 molecular weight band (lane 3). The inclusion of 400-fold molar  
15 excess of unlabeled Oncostatin M during the binding period specifically competed out the radioactivity associated with this band (lane 4). Therefore, applicants conclude that the Oncostatin M receptor on human endothelial cells is similar in structure and function to the Oncostatin M  
20 receptor on bovine endothelial cells, as well as to the Oncostatin M receptor on human cells of non-endothelial origin (lanes 1 and 2).

25 7. EXAMPLE: INDUCTION OF FIBRINOLYTIC ACTIVITY IN AORTIC ENDOTHELIAL CELLS BY ONCOSTATIN M

The experiments described below demonstrate that Oncostatin M induces endothelial cell-associated fibrinolysis in vitro.

30 7.1. MATERIALS AND METHODS

7.1.1. CELL CULTURE

Bovine aortic endothelial cells (BAEC) were prepared as described (Schwartz, 1978, In Vitro 4: 966-980) and  
35 cultured as follows. BAECs were grown at 37 degrees C to

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confluence in 24-well tissue culture plates ( $4 \times 10^5$  cells) with minimal essential medium (MEM/F-10 1:1) supplemented with 10% fetal bovine serum. Serum-containing medium was removed, monolayers washed twice in Dulbecco's phosphate buffered saline (PBS) and replaced with fresh serum-free MEM/F-10 prior to treating the cells with cytokines and assaying for plasminogen activator activity. Determinations of plasminogen activator (PA) activity were made following 72 hour incubations with cytokines at 37 degrees C/ 95% CO<sub>2</sub>-air atmosphere. Cell viability was greater than 98% as determined by trypan blue dye exclusion. Cell numbers were determined by hemacytometer counts.

7.1.2. PLASMINOGEN ACTIVATOR ACTIVITY ASSAY

Plasminogen activators (PA) catalyze the conversion of plasminogen to the active proteinase plasmin which acts directly to cleave fibrin molecules. The following assay employs plasminogen as the substrate for activation by PA, which activation is measured by detecting resulting fibrinolytic activity on a synthetic peptide.

Following treatment of BAECs with various cytokines, conditioned media was removed and stored at -70 degrees C for subsequent analysis. Monolayers were washed twice with PBS and tested for cell-associated PA activity using a two-step enzyme assay (Searls, 1980, *Analyt. Biochem.* 107: 64). Briefly, duplicate wells were incubated for 1 hour at 37 degrees C with saturating quantities of plasminogen substrate in 300  $\mu$ l serum-free medium. An equal volume of a synthetic chromogenic peptide, H-D-val-leu-lys-p-NA (Kabi Virtum, Sweden), at 1 mg/ml in 210 mM lysine buffer, pH 8.9, was then added and cells were allowed to incubate further for up to 2 hours. The synthetic peptide comprises the sequence of the fibrin molecule recognized and cleaved

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by plasmin. Proteolytic cleavage by plasmin releases p-nitroaniline from the peptide which can be detected spectrophotometrically. Thus, the assay is designed to measure changes in plasminogen activator activity by measuring plasminogen-dependent lysis of the synthetic peptide.

Enzyme activity was quantified by measuring liberated p-nitroaniline on a spectrophotometer at 405 nm and calibrated by comparison with a standard of 0.025 Plough Units purified uPA (Calbiochem) run in parallel with the cell samples. Optical density (OD) values were normalized to cell number and expressed as relative PA activity per  $10^6$  cells. To determine the level of secreted PA activity by BAECs, the conditioned media was thawed, clarified by centrifugation, and 200  $\mu$ l aliquots analyzed as described above.

#### 7.1.3. ONCOSTATIN M RECEPTOR ASSAY

Highly purified human Oncostatin M was radiolabeled by the IODO-GEN procedure (Fraker and Speck, 1978, BBRC 80: 849) to a specific activity of 52  $\mu$ Ci/ $\mu$ g. Radioreceptor assays were conducted in situ on confluent monolayers of BAECs grown in 24-well tissue culture plates ( $4 \times 10^5$  cells/well) in duplicate. Monolayers were first washed twice with binding buffer (Dulbecco's MEM + 0.1% bovine serum albumin + 15 mM HEPES) and then 250  $\mu$ l binding buffer containing 1 ng/ml radiolabeled Oncostatin M and variable amounts of unlabeled Oncostatin M were added to the monolayers. Cells were incubated at 23 degrees C for 3 hours to maintain steady state binding (Linsley et al., 1989, J. Biol. Chem. 264: 4282). Following the incubation period, cells were washed with cold binding buffer and solubilized in 1N NaOH. Radioactivity was detected by a gamma spectrophotometer and data plotted according to the

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method of Scatchard (Scatchard , 1949, Ann. N.Y. Acad. Sci. 51: 660). Non-specific binding was measured in the presence of a 400-fold molar excess of unlabeled Oncostatin M.

5

## 7.2. RESULTS

### 7.2.1. SPECIFIC STIMULATION OF PLASMINOGEN ACTIVATOR ACTIVITY BY ONCOSTATIN M

To determine the effect of Oncostatin M on the  
10 regulation of endothelial cell-mediated fibrinolytic  
activity, the ability of Oncostatin M to induce the  
synthesis of plasminogen activators (PAs) capable of  
catalyzing the conversion of plasminogen to bioactive  
plasmin was examined. Elevated PA levels, resulting in a  
15 corresponding increase in bioactive plasmin levels, was  
detected on Oncostatin M treated BAECs as well as in  
treated cell supernatants.

The results presented in Table III indicate that  
Oncostatin M dramatically and specifically stimulates the  
20 expression of PA activity. Conditioned media collected  
from Oncostatin M treated cells exhibited more than 12  
times more PA activity than conditioned media from  
untreated cells. In addition, Oncostatin M specifically  
induced plasminogen-dependent fibrinolytic activity rather  
25 than a protease capable of directly cleaving the synthetic  
peptide; conditioned media from Oncostatin M-treated cells  
with plasminogen substrate generated 76 times more activity  
than treated conditioned media alone. These results show  
that Oncostatin M specifically induces the synthesis and/or  
30 secretion of active plasminogen activator molecules and/or  
inhibits the expression or function of plasminogen  
activator inhibitors (PAI1 and PAI2).

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TABLE III<sup>1</sup>

## STIMULATION OF PA ACTIVITY BY ONCOSTATIN M

| 5  | TEST SAMPLE  | OD <sub>405</sub> |
|----|--|-------------------|
| 10 | Fresh MEM/F-10 alone   | 0.005             |
|    | Fresh MEM/F-10 + U-PA  | 0.004             |
|    | Plasminogen alone  | 0.000             |
| 15 | Plasminogen + u-PA   | 0.180             |
|    | CM <sup>2</sup> from untreated BAECs alone   | 0.002             |
| 20 | CM from untreated BAECs + plasminogen  | 0.080             |
|    | CM from Oncostatin M-treated BAECs alone   | 0.013             |
|    | CM from Oncostatin M-treated BAECs + plasminogen   | 0.985             |
| 25 | 1 BAECs (3 X 10 <sup>5</sup> cells) were treated for 27 hours with 900 pM Oncostatin M and the level of plasminogen-dependent proteolytic activity released into the media determined as described in Section 7.1.2. |                   |
| 30 | 2 Conditioned media  |                   |

In order to ascertain which form of plasminogen activator activity may be stimulated by Oncostatin M treatment (t-PA or u-PA), BAECs were preincubated with a neutralizing anti-u-PA monoclonal antibody prior to measuring cell-associated activity. Cells were washed twice in fresh serum free media and incubated for 1 hour at 23 degrees C in the presence or absence of 30 µg/ml anti-u-PA antibody (purified MAb 4B1D8-3.1 ; Gladstone and Enghart, manuscript in preparation) in a total volume of 300 µl. Following incubation, the cells were again washed and PA activity assayed as described in Materials and Methods, supra. Cells treated with 2.7 nM Oncostatin M for

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72 hours measured an OD<sub>405</sub> of 5.51 without antibody preincubation and 2.65 following antibody preincubation, a decrease of 52%. Therefore, Oncostatin M appears to cause a significant increase of u-PA expression and possibly an increase in t-PA expression as well.

There is a high degree of tissue specificity in the Oncostatin M induction of PA, as there is for induction of MHC antigens. When mononuclear blood cells are incubated with Oncostatin M at concentrations up to 10 ng/ml for 1 to 2 days, no change in PA activity is seen.

Other cytokines were tested for their ability to affect cell surface expression of PA activity. In contrast to the observed three-fold stimulation of cell-associated PA activity by 10 nM Oncostatin M, none of the other cytokines tested were able to stimulate this activity (FIG. 3). In fact, equimolar concentrations of TNF- $\alpha$  and TGF- $\beta$  decreased PA activity by 56% and 95% respectively. Similarly, in a separate experiment, 13 pM interleukin-1 (IL-1) decreased PA activity by 62%.

The effect of recombinant Oncostatin M on PA activity was also measured and compared to the effect observed with the native molecule. FIG.4 shows that recombinant Oncostatin M stimulates PA activity over the same dose range as native Oncostatin M, both preparations yielding an ED<sub>50</sub> of 217 pM or 6.5 ng/ml indicating identical potency.

#### 7.2.2. BAEC CELL-SURFACE RECEPTORS FOR ONCOSTATIN M

BAECs were analyzed for the presence of Oncostatin M cell-surface receptors as described in Section 7.1.3., supra. Competitive binding experiments were performed at near saturation conditions (FIG. 5). Analysis of Scatchard plots revealed the presence of at least two classes of cell-surface binding sites on BAECs as indicated by the curvilinear isotherm shown in FIG. 6. When analyzed by the

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two site model, BAECs were found to possess a total receptor concentration of 30,000 sites/cell, 495 of which correspond to a high affinity class ( $K_d=5.8$  pM) and 29,505 of which correspond to a low affinity class ( $K_d=1.0$  nM).  
5 Half-maximal receptor occupancy occurred at 2 ng/ml (67 pM) Oncostatin M. Maximum stimulation of PA activity (90%) required 30 ng/ml Oncostatin M, equivalent to about 80% receptor occupancy, suggesting that the low affinity/high capacity binding site may be involved in the mechanism by  
10 which Oncostatin M stimulates PA activity.

#### 8. EXAMPLE: ANTIPROLIFERATIVE EFFECTS OF ONCOSTATIN M ON ENDOTHELIAL CELLS

The studies described herein demonstrate that  
15 Oncostatin M inhibits the serum- and bFGF-induced proliferation of endothelial cells in vitro without inducing directional migration chemotaxis in monocytes.

##### 8.1. GROWTH INHIBITION ASSAYS

20 Two techniques were employed for measuring the inhibition of endothelial cell growth by Oncostatin M, cell quantitation and incorporation of radiolabeled nucleotide into DNA. For the cell quantitation assay, bovine aortic endothelial cells (BAECs) were plated at low density (1  
25  $\times 10^4$  cells/well) in 96-well tissue culture plates (Falcon) containing minimal essential media (Gibco) supplemented with 10% fetal bovine serum (Hyclone). Following a 4 hour incubation at 37 degrees C, triplicate wells were treated with increasing concentrations of Oncostatin M and  
30 incubated for an additional 72 hours. Monolayers were treated with 0.25% trypsin and the total number of cells per well was quantitated using a hemacytometer.

For measuring the incorporation of radiolabeled nucleotide into DNA, fetal bovine heart endothelial (BHE)

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cells (ATCC No. CRL 1395) were plated at low density ( $1 \times 10^4$  cells/well) in 96-well tissue culture plates (Falcon) containing DMEM (Gibco) supplemented with 10% FBS (Hyclone). Following a 4 hour incubation at 37 degrees C, triplicate wells were treated with bFGF alone or in combination with increasing concentrations of Oncostatin M. After 48 hours incubation at 37 degrees C, wells were treated with 0.05  $\mu$ Ci of 5-[ $^{125}$ I]-iodo-2'-deoxyuridine (Amersham) and incubated for an additional 24 hours. Monolayers were washed with PBS, fixed in 95% methanol, air-dried, and incorporated radioactivity was solubilized in 200  $\mu$ l 1N NaOH. DNA synthesis was measured by quantitating the amount of radiolabeled nucleotide incorporated into the DNA of actively growing cells. After 72 hours treatment, unlabeled cells were trypsinized and counted using a hemacytometer and the results compared to the observed level of DNA synthesis.

#### 8.2. MONOCYTE CHEMOTAXIS ASSAY

Human peripheral blood mononuclear cells (PBMCs) were prepared from blood using Ficoll gradient separation and utilized in the chemotaxis assay. The assay was conducted in poly(vinylpyrrolidone)-free polycarbonate 8  $\mu$ m filters (Nucleopore Corp.; Pleasanton, CA) in 48-well micro chemotaxis chambers (Neuro Probe; Cabin John, MD). Briefly, bottom chambers were filled with 55  $\mu$ l PBMCs in suspension ( $10^6$  cells/ml). The assembled chamber was incubated in a humidified atmosphere of 5% CO<sub>2</sub>/95% air at 37 degrees C for 3 hours. Cells that had migrated to the reverse side of the filter were fixed and stained by the Diff-Quik procedure (American Scientific Products; McGaw Park, IL) and five randomly chosen fields were enumerated by light microscopy at high power for cells displaying characteristic monocyte staining. Monocyte migration in

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response to putative chemoattractants was expressed as the mean number of monocytes per high power field (HPF),  $n=5$ . Response to the chemotactic tripeptide, fMET-Leu-Phe (Sigma; St. Louis, MO) was considered maximal.

5

### 8.3 RESULTS

Angiogenesis requires that endothelial cells migrate and proliferate in response to angiogenic stimuli. Confluent cultures of BAECs respond to bFGF by increasing the saturation density of the monolayer. When grown to confluence, BAECs became density arrested at a concentration of  $4-5 \times 10^5$  cells/well. Exposure to 5 ng/ml bFGF induced these cells to divide further, reaching a density of  $8-10 \times 10^5$  cells/well. In order to determine whether Oncostatin M could act as an anti-proliferative agent by blocking bFGF-stimulated endothelial cell growth, confluent cultures of BAECs were exposed to bFGF in the presence or absence of Oncostatin M. As shown in FIG. 7, Oncostatin M blocks the mitogenic action of bFGF in a dose-dependent manner. Cell proliferation was inhibited by low concentrations of Oncostatin M,  $ED_{50} = 0.4$  ng/ml or 13 pM.

The susceptibility of low density BAECs to the antiproliferative effects of Oncostatin M was assayed as described in Section 8.1., supra., as illustrated in FIG. 8. In the absence of Oncostatin M, cultures initially seeded at  $1 \times 10^4$  cells/well reached a density of  $8 \times 10^4$  cells/well after 72 hours incubation. In contrast, when grown in the presence of Oncostatin M, low density BAECs failed to respond to the mitogenic action of 10% serum and remained at the initial cell density ( $ED_{50} = 19$  pM).

Another endothelial cell line, BHE, isolated from bovine heart, which strictly requires bFGF to support its growth, was assayed for its sensitivity to Oncostatin M as described in Section 8.1., supra. FIG. 9 shows that

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Oncostatin M inhibits the bFGF-dependent growth of these cells in a dose-dependent manner ( $ED_{50} = 16$  pM). In addition to DNA labeling, cell number was determined. Cell density in the presence of bFGF alone increased from  $1.8 \times 10^3$  cells/well to  $3.8 \times 10^3$  cells/well, and together with  
5  $10^3$  cells/well to  $3.8 \times 10^3$  cells/well, and together with Oncostatin M remained at  $1 \times 10^3$  cells/well.

Certain cytokines demonstrating angiogenic properties in vivo have been shown to attract monocyte-macrophages to the site of injection. It is now believed that monocyte-  
10 macrophages induce neovascularization through the production and release of angiogenic factors (Thakral et al., 1979, J. Surg. Res. 26: 430). The ability of cytokines to stimulate chemotactic responses in monocytes may predict their ability to induce angiogenesis in vivo.  
15 Oncostatin M was evaluated for its capacity to stimulate chemotaxis using the assay described in Section 8.2., supra. The results presented in Table IV demonstrate that unlike the chemotactic activity reported for IL-1 (Luger et al., 1983, J. Immunol. 131: 816), TNF- $\alpha$  (Ming et al., 1987,  
20 J. Immunol. 138: 1469) and TGF- $\beta$  (Wahl et al., 1987, Proc. Natl. Acad. Sci. U.S.A. \_\_\_\_\_), Oncostatin does not induce directional migration chemotaxis in monocytes. Monocytes from a preparation of PBMCs were stimulated to migrate across a porous membrane barrier in the direction of  
25 chambers containing the potent chemoattractant fMET-Leu-Phe but, in contrast, chambers containing Oncostatin M alone had no effect on cell migration.

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TABLE IV

EFFECT OF ONCOSTATIN M ON MONOCYTE CHEMOTAXIS

| <u>ADDITIONS TO LOWER COMPARTMENT</u> | <u>NUMBER of MONOCYTES/hpf</u> |
|---------------------------------------|--------------------------------|
| MEM/F-10 medium                       | 6 ± 3                          |
| fMet-Leu-Phe, 10 <sup>-7</sup> M      | 83 ± 4                         |
| Oncostatin M, 50 ng/ml                | 6 ± 2                          |

9. EXAMPLE: CHARACTERIZATION OF MORPHOLOGICAL CHANGES  
INDUCED BY ONCOSTATIN M ON ENDOTHELIAL CELLS

The following studies characterize the morphological effects induced in bovine endothelial cells by Oncostatin M in vitro.

9.1. CELL CULTURE

Bovine aortic endothelial cells (BAECs) were cultured as described in Section 7.1.1., supra.

9.2. LEUKOCYTE ADHERENCE ASSAY

BAECs were grown to confluence in glass slide chambers (Lab-Tek; NUNC Inc.) in the presence of 10% fetal bovine serum. Cultures were switched to serum-free media as described in Section 7.1.1., a, treated with 1.7 nM Oncostatin M, and allowed to incubate for 24 to 48 hours. Following incubation the cell monolayers were washed three times with fresh serum-free media. Then, 250 µl serum-free media containing 5 X 10<sup>4</sup> phytohemagglutinin-activated, non-adherent leukocytes were added to the chambers and incubated for 60 minutes at 23 degrees C to allow for cell-cell interaction (leukocytes were prepared from human peripheral blood mononuclear cells after a 72 hour incubation at 37 degrees C on a plastic surface). Non-

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adhering leukocytes were removed by washing the monolayer three times with fresh serum-free media. BAECs were then fixed, stained (Diff-Quik procedure; American Scientific Products) and examined microscopically for leukocyte binding (primarily lymphoblasts). Lymphoblast binding was quantitated by averaging the number of cells observed in five randomly selected high power fields.

9.3. ONCOSTATIN M INDUCES MORPHOLOGICAL CHANGES IN BAECs

The photomicrographs in FIG. 10 show the morphological effects of Oncostatin M on BAECs. Oncostatin M induces alterations in BAEC monolayer architecture: the typical "cobblestone" pattern of cell alignment is lost and replaced by elongated cells with wider intercellular spacing. The observed intercellular "retraction" implies that Oncostatin M induces alterations in endothelial cell-surface properties.

The endothelial cell-surface has been shown to preferentially bind a variety of leukocytes through identified and putative intercellular adhesion molecules (Cotran and Pober, Endothelial Cell Biology in Health and Disease; Simionescu and Simionescu, Eds., 1988). It is known that lymphocyte adhesion is an inducible property of endothelial cells. BAECs were therefore examined for leukocyte adhesion properties following Oncostatin M treatment. The results demonstrate that Oncostatin M induces the adhesion of human leukocytes to the surface of BAEC monolayers in a time-dependent manner (FIG. 11).

To examine the mechanism by which Oncostatin M induces leukocyte adhesion, BAECs were allowed to preincubate with a monoclonal antibody (LB-2, 20 µg/ml; provided by Dr. E. A. Clark of the Regional Primate Research Center at Washington University, Seattle, WA) specific for Intercellular Adhesion Molecule-1 (ICAM-1) prior to

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Oncostatin M treatment. Preincubation with the anti-ICAM-1 MAb resulted in a 62% decrease in leukocyte adhesion suggesting that Oncostatin M induces leukocyte adhesion by upregulating the expression of heterotypic intercellular adhesion molecules such as ICAM-1. This action of Oncostatin M may extend to other leukocyte subsets and endothelial cell types in view of observations made with IL-1, IFN -gamma, TNF- $\alpha$ , and lipopolysaccharides, which also increase adhesion by other leukocyte subsets (Makgobe et al., 1983, Nature (London) 351: 86; Dustin and Springer, 1988, J. Cell. Biol. 107: 321).

10. ONCOSTATIN M-INDUCED STIMULATION OF INTERLEUKIN-6 SYNTHESIS IN HUMAN ENDOTHELIAL CELLS

10.1. MATERIALS AND METHODS

10.1.1 PREPARATION OF HUMAN UMBILICAL VEIN ENDOTHELIAL CELLS

First passage cultures of human umbilical vein endothelial cells (HUVECs) were obtained from Cell Systems (Kirkland WA) as prepared according to the method of Wall et al., 1978, J. Cell. Physiol. 96:203. Cells were passaged with collagenase and grown to confluence on gelatin-coated plasticware in CS-1 defined serum-free medium (Cell Systems) substituted with heparin and recombinant ECGS (Bionetics). Cells were given fresh unsupplemented medium at least 12 hours prior to experimentation.

10.1.2. GROWTH INHIBITION ASSAY

The breast carcinoma cell line, ZR-75-30, was obtained from the American Type Culture Collection, Rockville, MD (catalog # CRL 1504). Cells were cultured in Dulbecco's minimal essential medium (GIBCO) supplemented with 10% fetal bovine serum (Hyclone). Cells were plated at  $1 \times 10^4$

cells/50 µl/well in 96-well tissue culture plates (Falcon). Following a 4 hour incubation at 37° C, cells were treated with test samples in triplicate. After 48 hours incubation, cells were treated with 50 µl of medium  
5 containing 0.05 µCi of 5-[<sup>125</sup>I]-iodo-2' deoxyuridine (Amersham) and incubated an additional 24 hours. Monolayers were washed with PBS, fixed in 95% menthol, air-dried, and incorporated radioactivity was solubilized in 200 µl 1N NaOH. DNA synthesis was measure by quantitating  
10 the amount of radiolabeled nucleotide incorporated into the DNA of actively growing cells. After 72 hours treatment, unlabeled cells were trypsinized and counted using a hemacytometer, indicating that the amount of radioactivity was directly proportioned to the total number of cells in  
15 the well.

#### 10.1.3. QUANTITATIVE MEASUREMENT OF IL-6 RELEASED FROM HUMAN UMBILICAL VEIN ENDOTHELIAL CELLS

A "sandwich" enzyme-linked immunosorbant assay, ELISA,  
20 for the quantitative determination of human IL-6 in tissue culture media, sera, and other fluids was commercially obtained from Research and Diagnostic Systems (Minneapolis, MN) and performed according to their recommended procedure. Briefly, samples are pipetted into micotiter plate wells  
25 which have been coated with an IL-6-specific monoclonal antibody and the IL-6, if any, is bound by the immobilized antibody. After washing away any unbound sample proteins, an enzyme-linked polyclonal antibody specific for IL-6 is added to the wells and allowed to bind to any IL-6 bound  
30 during the first incubation. Following a wash to remove any unbound antibody-enzyme reagent, a substrate solution is added to the wells causing color to develop in proportion to the amount of IL-6 bound in the initial step. Color is monitored at 405 nM on a spectrophotometer and  
35 compared to the value for a known amount of IL-6 from a

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standard curve. Individual samples are run in duplicate, with a standard error of  $\pm 2\%$ . The minimal detectable dose of IL-6 was 3.5 pg/ml.

5      10.1.4.      PREPARATION OF TOTAL CELLULAR RNA FROM HUMAN  
                 UMBILICAL VEIN ENDOTHELIAL CELLS AND NORTERN BLOT

Total cellular RNA was isolated by lysing human umbilical vein endothelial cells in guanidium isothiocyanate followed by recovery of RNA by centrifugation through cesium chloride (Maniatis et al., 1982, Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, Cold Spring Harbor, NY). Then, 5 µg/sample were fractionated on 1.2% agarose gel with 6% formaldehyde and blotted onto nylon membranes (Hybond-N, 15 Amersham) for Northern blot analysis. RNA from a lung carcinoma cell line, H2981, was used as a positive control for IL-6 expression. Hybridization was performed at 37° C in a solution containing 50% formamide, 50mM sodium phosphate pH7.0, 5 x SSC, 100 µg/ml denatured salmon sperm 20 DNA, 10X Denhardt's solution and  $5 \times 10^5 - 10^6$  dpm/µg/ml of labeled IL-6 exon-specific oligonucleotide probe (catalog #BPR 32, Research and Diagnostic Systems, Minneapolis, MN). This particular probe is specific for 4 separate exon 25 regions of the IL-6 gene and was labeled at the 5' end to a specific activity of  $4.2 \times 10^9$  dpm/µg using a T4 polynucleotide kinase and  $\gamma$ -<sup>32</sup>P-ATP labeling procedure as recommended by Research and Diagnostic Systems. After hybridization was complete, the membrane was washed in 6 x SSC + 0.1% SDS at 30° C for 20 minutes. The membranes were 30 then exposed to x-ray film with an intensifying screen at -70° C for 48 hours.

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10.2. RESULTS10.2.1. IL-6 BIOACTIVITY FROM ONCOSTATIN M  
STIMULATED ENDOTHELIAL CELLS: INHIBITION OF  
5 HUMAN BREAST CARCINOMA CELL GROWTH

Confluent cultures of human umbilical vein endothelial cells (HUVECs) were treated with and without 100 ng/ml recombinant Oncostatin M for 72 hours. The conditioned  
10 media was collected, clarified by centrifugation and stored at -20° C prior to use. The growth of human breast carcinoma cells, ZR-75-30, was monitored by using the growth inhibition assay described in Section 10.1.3., *supra* following treatment with recombinant Oncostatin M,  
15 recombinant IL-6, the conditioned media from untreated HUVECs, the conditioned media from Oncostatin M-treated HUVECs and the conditioned media from Oncostatin M-treated HUVECs preincubated for 1 hour at 37° C with anti-IL-6 neutralizing antibodies. The results of this experiment  
20 are presented in Table V.

Recombinant Oncostatin M demonstrated no significant inhibitory effect on the growth of ZR-75-30 cells (14%), whereas a ten-fold lower dose of recombinant IL-6 was highly active in this regard (88%). These results indicate  
25 that ZR-75-30 cells are considerably less sensitive to growth inhibition by Oncostatin M than by IL-6. HUVEC conditioned media (1:40 dilution) was also ineffective at inhibiting the growth of ZR-75-30 cells (8%), while the conditioned media from Oncostatin M-treated HUVECs (1:40  
30 dilution) demonstrated a dramatic growth inhibitory effect (70%). The results indicate that Oncostatin M treatment stimulates the release of a tumor cell suppressor molecule from HUVECs which, in contrast to Oncostatin M, acts directly to inhibit the growth of the breast carcinoma  
35 cells. When the conditioned media from Oncostatin M-



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treated HUVECs is preincubated with neutralizing antibodies to IL-6 (anti-IL-6), the inhibitory activity of the sample is completely blocked. Therefore, the tumor cell suppressor molecule induced by Oncostatin M is immunologically identical to IL-6.

TABLE V

IL-6 BIOACTIVITY ZR-75-30 BREAST CARCINOMA CELLS<sup>1</sup>

| <u>SAMPLE</u>            | <u>[<sup>125</sup>I]-IUdR<br/>Incorporation</u> | <u>% Inhibition</u> |
|--------------------------|---|---------------------|
| medium alone             | 11,852 +/- 324 cpm                              | 0                   |
| 15 Onco M, 25 ng/ml      | 10,088 +/- 527                                  | 14                  |
| IL-6, 2.5 ng/ml          | 1,467 +/- 86                                    | 88                  |
| CM alone                 | 10,855 +/- 5                                    | 8                   |
| Onco M/CM                | 3,703 +/- 162                                   | 70                  |
| 20 Onco M/CM + Anti IL-6 | 10,892 +/- 207                                  | 8                   |

1. ZR-75-30 cells were treated for 72 hours in the presence of 10% fetal bovine serum. Cell proliferation was measured according to Section 10.1.2., supra, and is presented in the table as percent (%) inhibition [cpm of medium alone-cpm of sample/cpm of medium alone] x 100. Conditioned medium (CM) was diluted 1:40 to minimize serum dilution in the bioassay. Anti-IL-6 was used at a concentration of 25 µg/ml.

#### 10.2.2. TIME AND DOSE REQUIREMENTS FOR ONCOSTATIN M STIMULATION OF IL-6 ACTIVITY IN ENDOTHELIAL CELLS

Aliquots of the conditioned media (CM) from HUVECs were taken at various time intervals following treatment with 100 ng/ml Oncostatin M. Samples were measured for IL-6 content utilizing the ELISA procedure described in Section 10.1.3., supra. As shown in FIG. 12, increases in IL-6 levels were observed as early as 2 hours post-treatment, and continued throughout the 24 hour period without reaching a maximal level. By 8 hours, IL-6 concentration in HUVEC media had risen from 0.8 ng/ml to 1.8 ng/ml, and to 27 ng/ml by 24 hours. These kinetics

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indicate a rapid response by HUVECs to Oncostatin M treatment.

FIG. 13 demonstrates the dose-dependent action of Oncostatin M on HUVECs when measured at 72 hours post-treatment, at which point the IL-6 content of CM had risen from 10 ng/10<sup>6</sup> cells to 110 ng/10<sup>6</sup> cells (> 10-fold). The effective dose for Oncostatin M ranged from 0.1 nM (3 ng/ml) to 10nM (300 ng/ml) with a half-maximal response, ED<sub>50</sub>, of 15-30 ng/ml. Therefore, Oncostatin M stimulates the release of immunoreactive IL-6 molecules from HUVECs in both a time and dose dependent manner.

#### 10.2.3. ONCOSTATIN M INDUCED EXPRESSION OF IL-6 mRNA IN HUMAN UMBILICAL VEIN ENDOTHELIAL CELLS

HUVECs were treated with and without 100 ng/ml recombinant Oncostatin M and incubated at 37° C for 6 hours. Cells were washed, solubilized, and their total RNA extracted as described in Section 10.1.4., *supra*. Total RNA from the human lung carcinoma cell line, H2981, was extracted and used as a positive control for expression of IL-6 mRNA. Northern blot analyses, performed as described in Section 10.1.4., *supra*, indicate that Oncostatin M significantly amplifies IL-6 mRNA levels (FIG. 14). Lane 1, FIG. 14, shows the 1.4 Kb mRNA species found in the positive control cell line, H2981. Lane 2, FIG. 14, indicates the low constitutive expression of IL-6 mRNA in untreated HUVECs. Lane 3 shows a significant amplification of IL-6 mRNA transcripts following Oncostatin M treatment (5-fold). Therefore, Oncostatin M induces the expression of higher levels of IL-6 mRNA in HUVECs, thus providing a molecular mechanism for the observed increases in IL-6 levels found in the CM of Oncostatin M-treated HUVECs.

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The present invention is not to be limited by the embodiments disclosed herein which are intended as single illustrations of one aspect of the invention and any which are functionally equivalent are within the scope of the  
5 invention. Indeed, various modifications of the invention, in addition to those shown and described herein, will become apparent to those skilled in the art from the foregoing description. Such modifications are intended to fall within the scope of the appended claims.

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WHAT IS CLAIMED IS:

1. A method for inhibiting endothelial tissue  
5 immunogenicity comprising treating the endothelial tissue  
with an effective amount of Oncostatin M so that the  
expression of MHC antigens on the endothelial cells is  
suppressed.
- 10 2. The method according to claim 1 in which the MHC  
antigens comprise class I HLA antigens.
3. The method according to claim 1 in which the MHC  
antigens comprise class II HLA antigens.  
15
4. The method according to claim 1 in which the  
Oncostatin M is covalently coupled to an antibody molecule  
that defines a cellular antigen.
- 20 5. The method according to claim 1 in which the  
Oncostatin M is covalently coupled to a hormone.
6. The method according to claim 1 in which the  
Oncostatin M is covalently coupled to a growth factor.  
25
7. The method according to claim 1 in which the  
Oncostatin M is covalently coupled to a cytokine.
8. The method according to claim 1 in which the  
30 Oncostatin M is encapsulated in a liposome.
9. The method according to claim 1 in which the  
Oncostatin M is encapsulated in a microcapsule.

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10. A method for increasing plasmin activity comprising administering Oncostatin M to an individual at a dose effective at stimulating endothelial cell-associated plasminogen activator activity.

5

11. A method for inducing fibrinolysis comprising administering Oncostatin M to an individual at a dose effective at stimulating endothelial cell-associated plasminogen activator activity.

10

12. The method according to claim 10 or 11 in which the Oncostatin M is covalently coupled to an antibody molecule that defines a cellular antigen.

15

13. The method according to claim 10 or 11 in which the Oncostatin M is covalently coupled to a hormone.

14. The method according to claim 10 or 11 in which the Oncostatin M is covalently coupled to a growth factor.

20

15. The method according to claim 10 or 11 in which the Oncostatin M is covalently coupled to a cytokine.

16. The method according to claim 10 or 11 in which the Oncostatin M is encapsulated in a liposome.

25

17. The method according to claim 10 or 11 in which the Oncostatin M is encapsulated in a microcapsule.

30

18. A method for inhibiting angiogenesis comprising administering Oncostatin M to an individual at a dose effective at inhibiting endothelial cell proliferation.

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19. The method according to claim 18 in which the Oncostatin M is covalently coupled to an antibody molecule that defines a cellular antigen.

5 20. The method according to claim 18 in which the Oncostatin M is covalently coupled to a hormone.

21. The method according to claim 18 in which the Oncostatin M is covalently coupled to a growth factor.

10

22. The method according to claim 18 in which the Oncostatin M is covalently coupled to a cytokine.

15 23. The method according to claim 18 in which the Oncostatin M is encapsulated in a liposome.

24. The method according to claim 18 in which the Oncostatin M is encapsulated in a microcapsule.

20 25. A method for improving the likelihood of transplanted organ functional success comprising administering Oncostatin M to a transplant recipient at a dose effective at inhibiting the expression of MHC antigen expression in donor organ vasculature.

25

26. The method according to claim 25 in which the transplanted organ is a heart.

27. The method according to claim 25 in which the  
30 transplanted organ is a lung.

28. The method according to claim 25 in which the transplanted organ is a kidney.

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29. The method according to claim 25 in which the transplanted organ is a liver.

30. The method according to claim 25 in which the  
5 MHC antigens comprise class I HLA antigens.

31. The method according to claim 25 in which the MHC antigens comprise class II HLA antigens.

10 32. The method according to claim 25 in which the Oncostatin M is covalently coupled to an antibody molecule that defines a cellular antigen.

33. The method according to claim 25 in which the  
15 Oncostatin M is covalently coupled to a hormone.

34. The method according to claim 25 in which the Oncostatin M is covalently coupled to a growth factor.

20 35. The method according to claim 25 in which the Oncostatin M is covalently coupled to a cytokine.

36. The method according to claim 25 in which the Oncostatin M is encapsulated in a liposome.  
25

37. The method according to claim 25 in which the Oncostatin M is encapsulated in a microcapsule.

38. The method according to claim 25 in which the  
30 Oncostatin M is co-administered with TGF- $\beta$ .

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39. A method for the treatment of thrombotic cardiovascular disease comprising administering Oncostatin M to an individual at a dose effective at enhancing  
5 thrombolysis.

40. The method according to claim 39 in which the Oncostatin M is co-administered with t-PA.

10 41. The method according to claim 39 in which the Oncostatin M is covalently coupled to an antibody molecule that defines a cellular antigen.

15 42. The method according to claim 39 in which the Oncostatin M is covalently coupled to a hormone.

43. The method according to claim 39 in which the Oncostatin M is covalently coupled to a growth factor.

20 44. The method according to claim 39 in which the Oncostatin M is covalently coupled to a cytokine.

45. The method according to claim 39 in which the Oncostatin M is encapsulated in a liposome.

25

46. The method according to claim 39 in which the Oncostatin M is encapsulated in a microcapsule.

30 47. A method for treating Kaposi's sarcoma lesions comprising administering Oncostatin M to an individual suffering from Kaposi's sarcoma at a dose effective at inhibiting neovascularization of the lesion.



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48. The method according to claim 47 in which the Oncostatin M is covalently coupled to an antibody molecule that defines a cellular antigen.

5 49. The method according to claim 47 in which the Oncostatin M is covalently coupled to a hormone.

10 50. The method according to claim 47 in which the Oncostatin M is covalently coupled to a growth factor.

51. The method according to claim 47 in which the Oncostatin M is covalently coupled to a cytokine.

15 52. The method according to claim 47 in which the Oncostatin M is encapsulated in a liposome.

53. The method according to claim 47 in which the Oncostatin M is encapsulated in a microcapsule.

20 54. A method of inducing the synthesis of interleukin-6 in an endothelial cell comprising contacting the endothelial cell with an effective amount of Oncostatin M.

25 55. The method according to claim 54 wherein the effective amount of Oncostatin M is in the range of 0.1nM to 10nM.

30 56. A method of inducing the synthesis of interleukin-6 messenger RNA in an endothelial cell comprising contacting the endothelial cell with an effective amount of Oncostatin M.

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57. A method of inhibiting the proliferation of endothelial cells comprising administering Oncostatin M in an amount effective at inducing the synthesis of interleukin-6.

5

58. A method of elevating the level of circulating interleukin-6 in an individual comprising administering to the circulatory system of the individual an amount of Oncostatin M effective at inducing the synthesis of  
10 interleukin-6 in the individual's vascular endothelium.

59. A method of inhibiting the proliferation of neoplastic cells comprising administering to endothelial cells adjacent to the neoplastic cells an amount of  
15 Oncostatin M effective at inducing the endothelial cells to secrete at least one cytokine capable of inhibiting the proliferation of the neoplastic cells.

60. The method according to claim 59 in which at  
20 least one cytokine includes interleukin-6.

61. The method according to claim 59 in which at least one cytokine includes granulocyte macrophage-colony stimulating factor.

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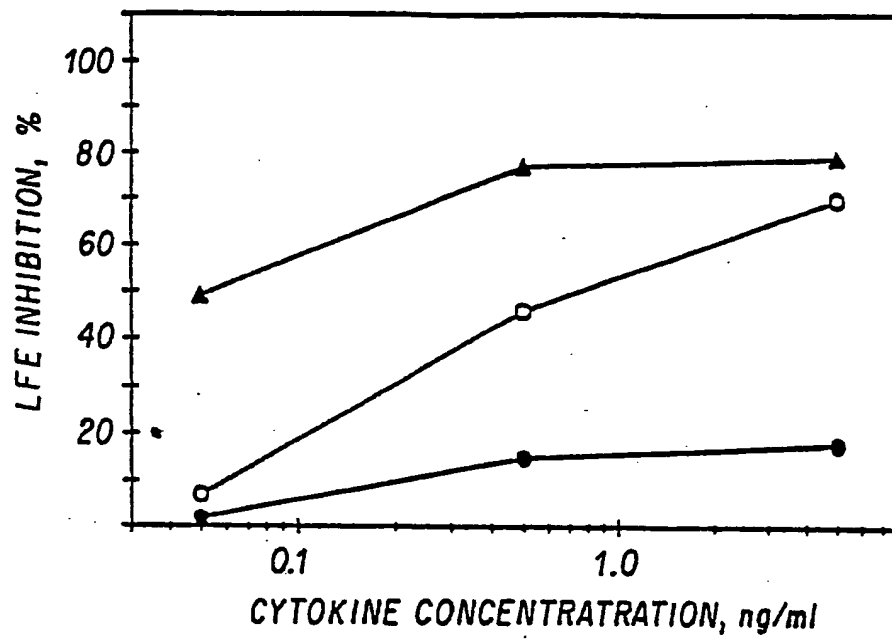


FIG. 1A

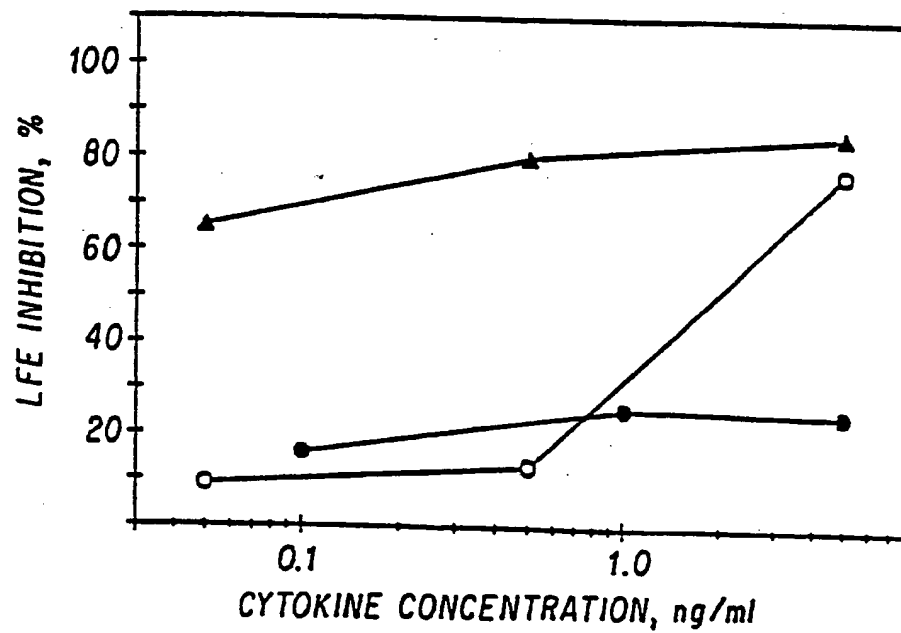


FIG. 1B

SUBSTITUTE SHEET

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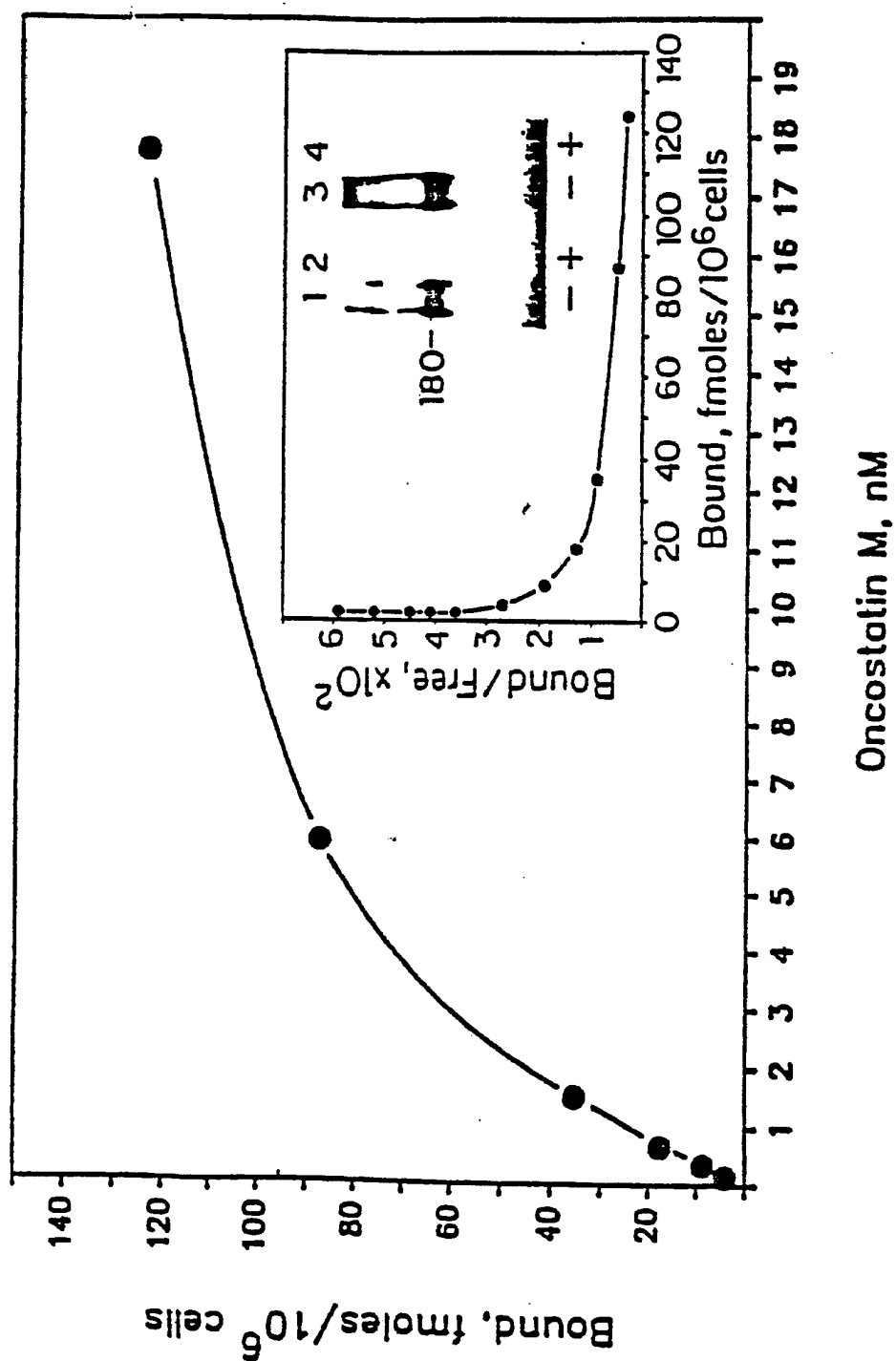


FIG. 2

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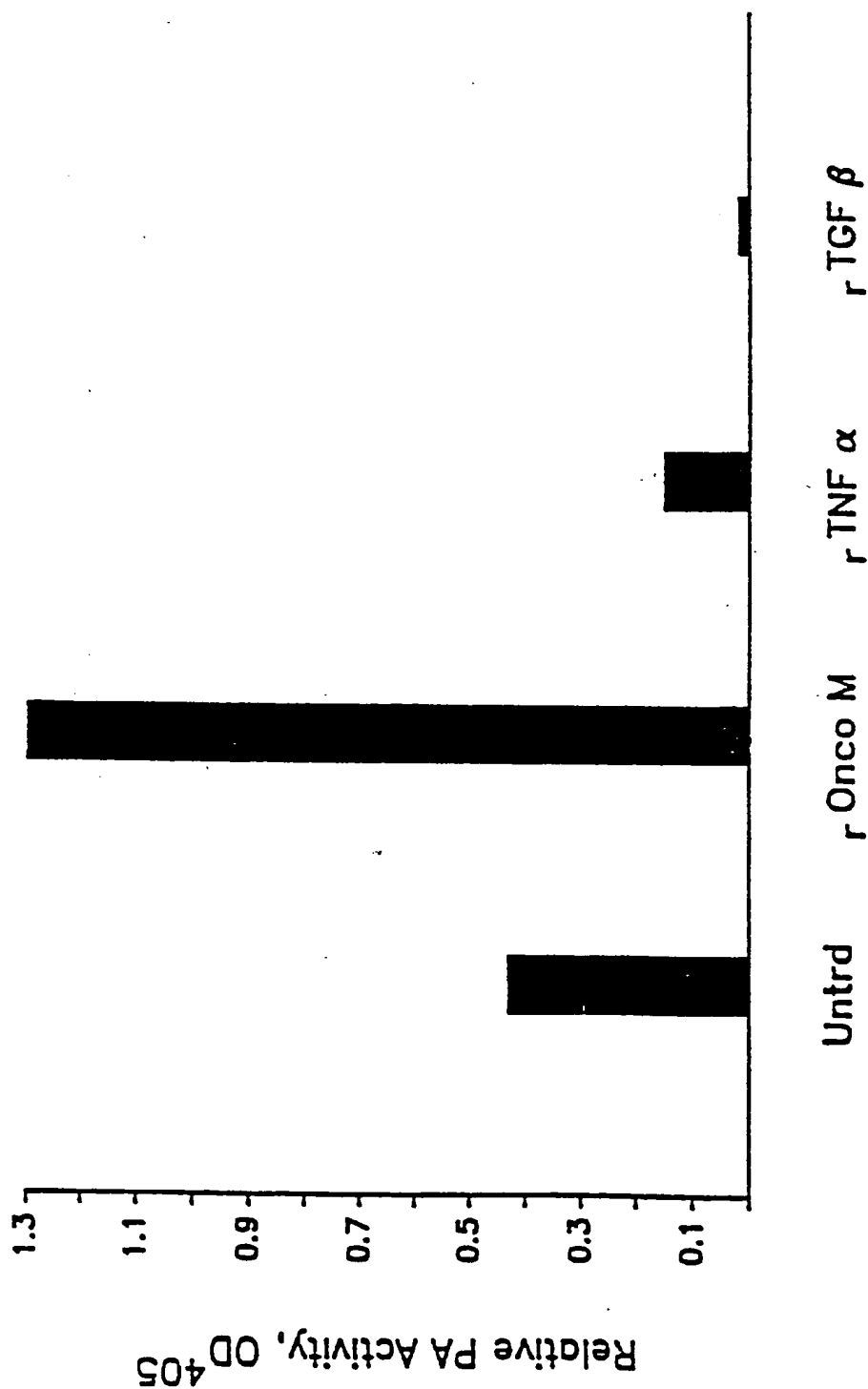


FIG. 3

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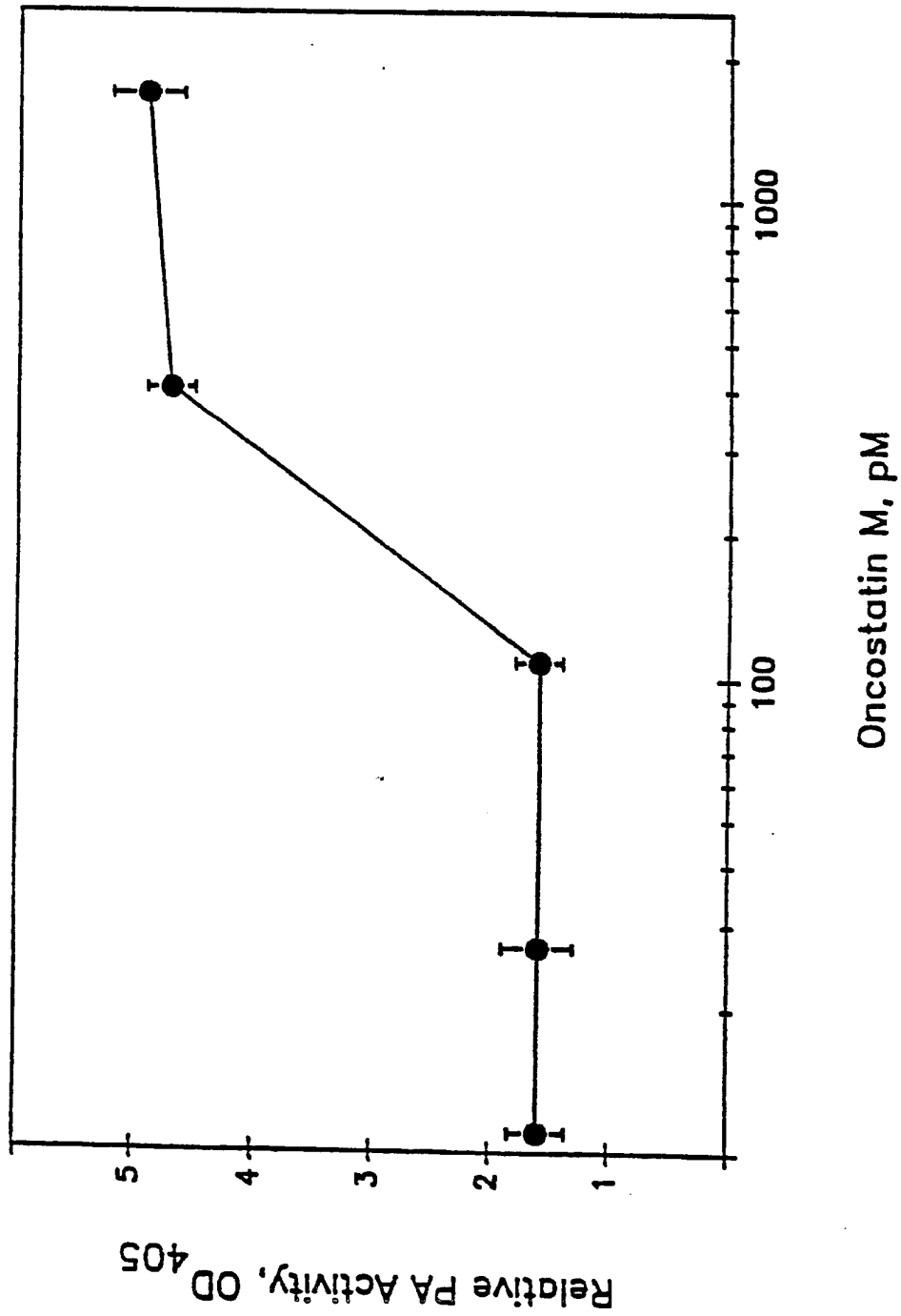


FIG. 4A

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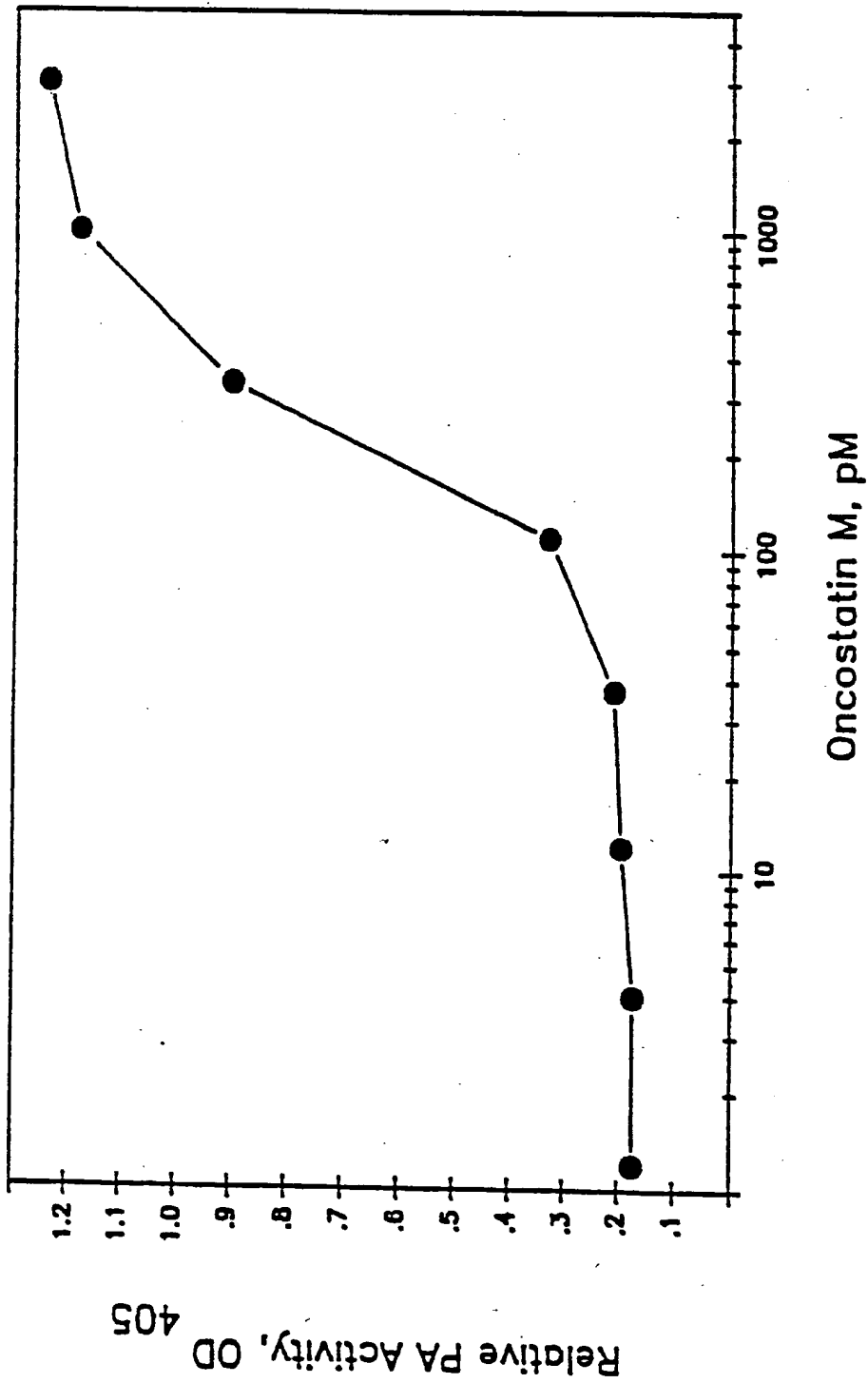


FIG. 4B

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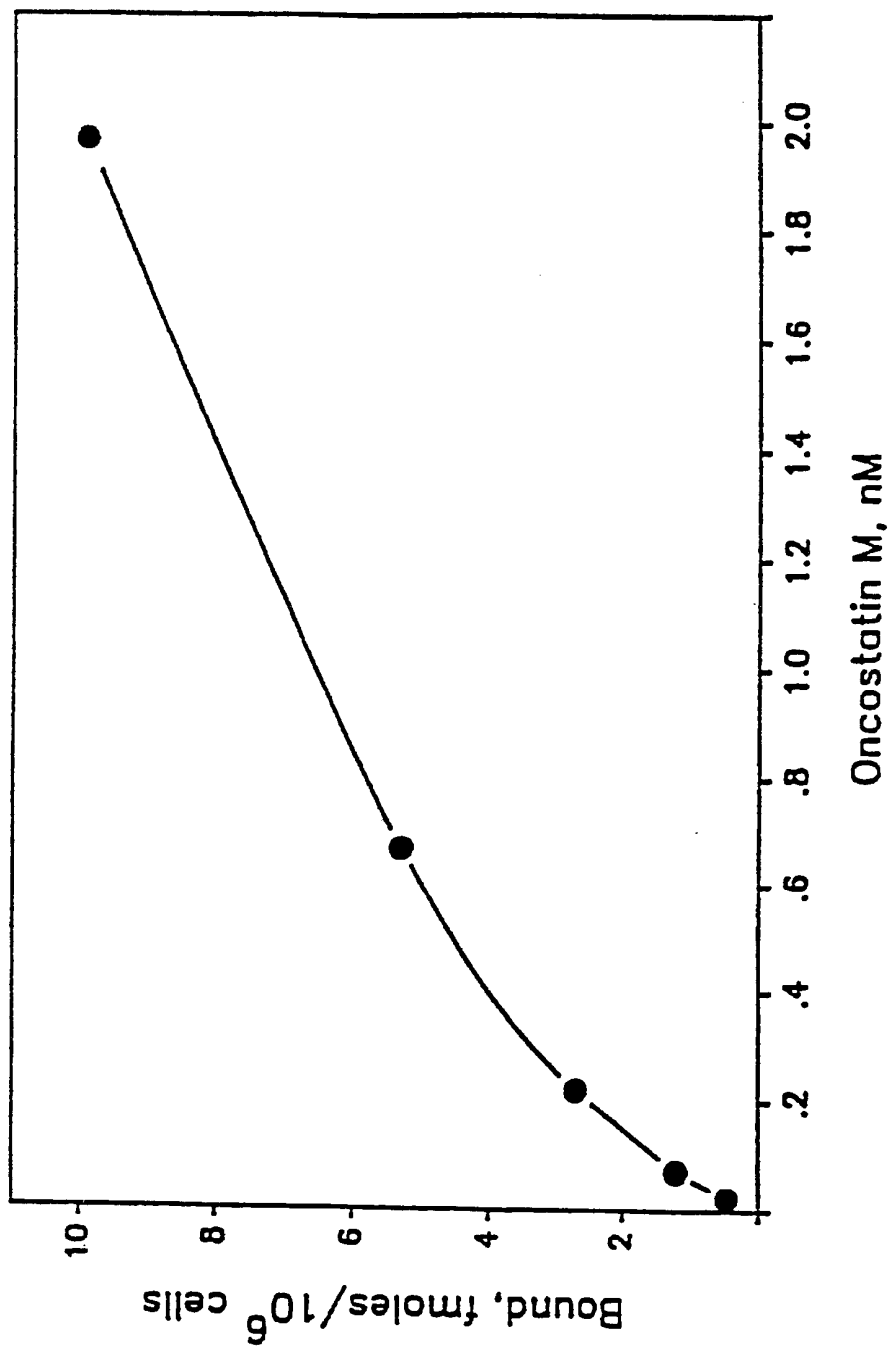


FIG. 5



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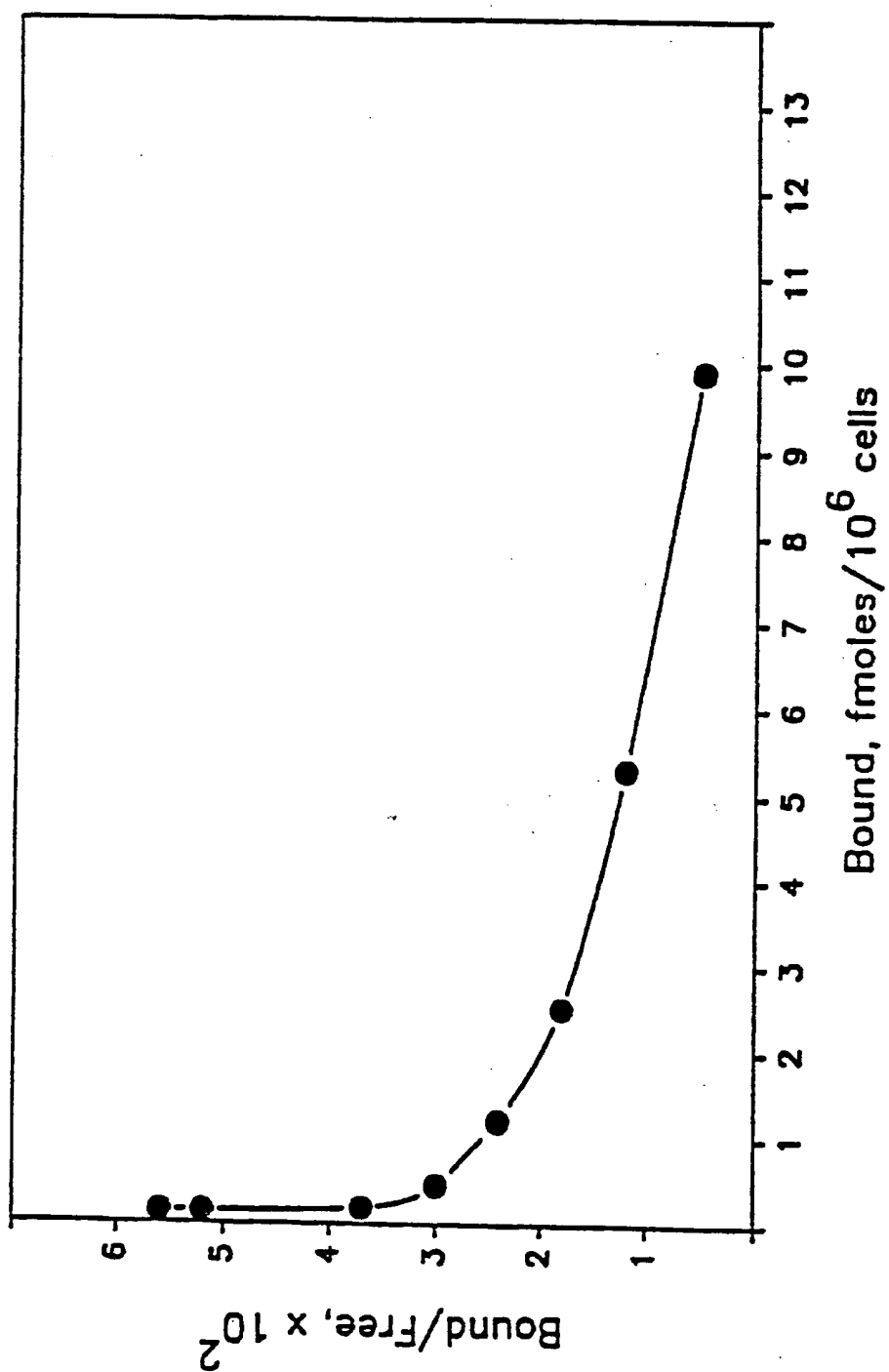


FIG. 6

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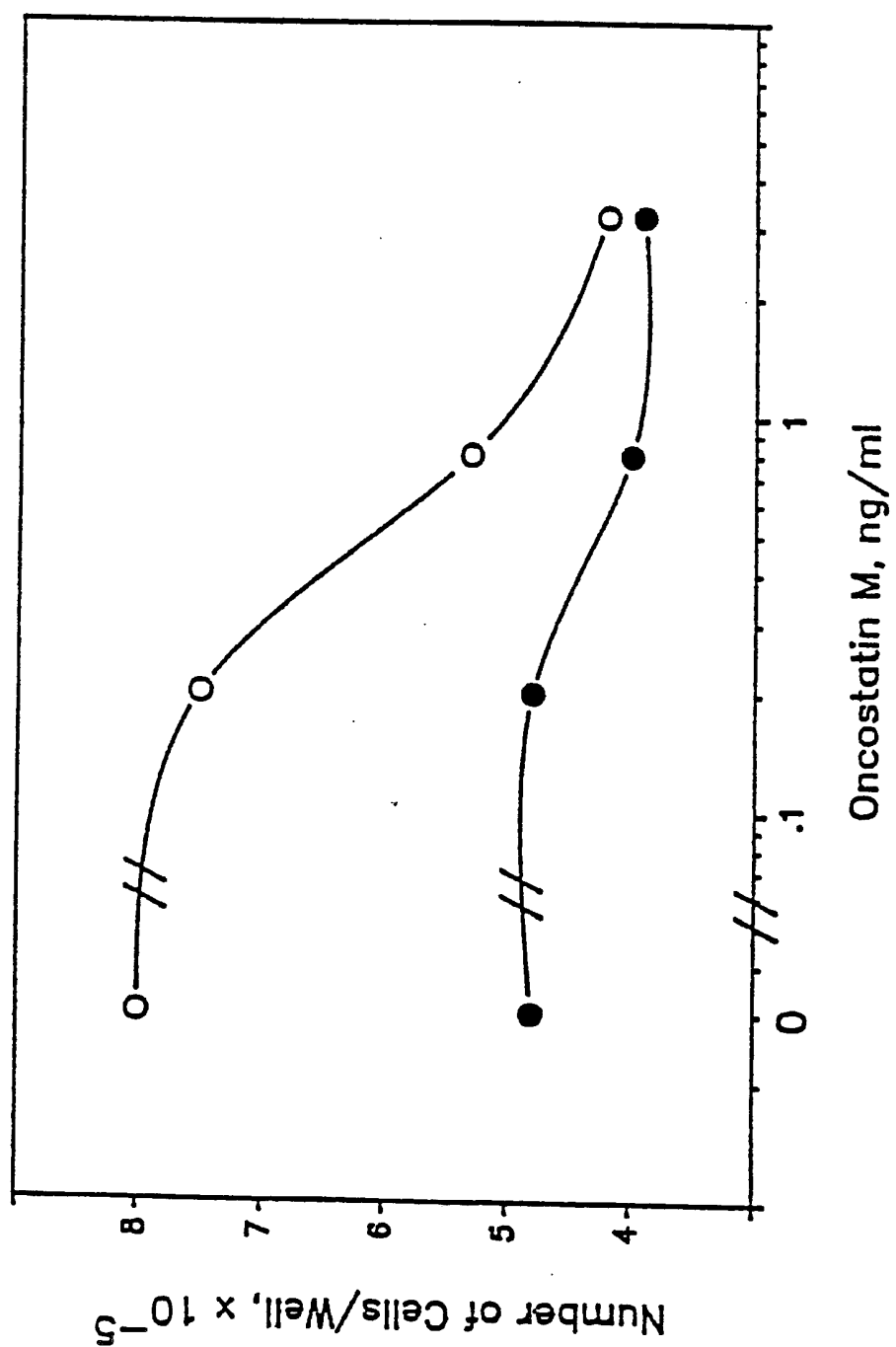


FIG. 7

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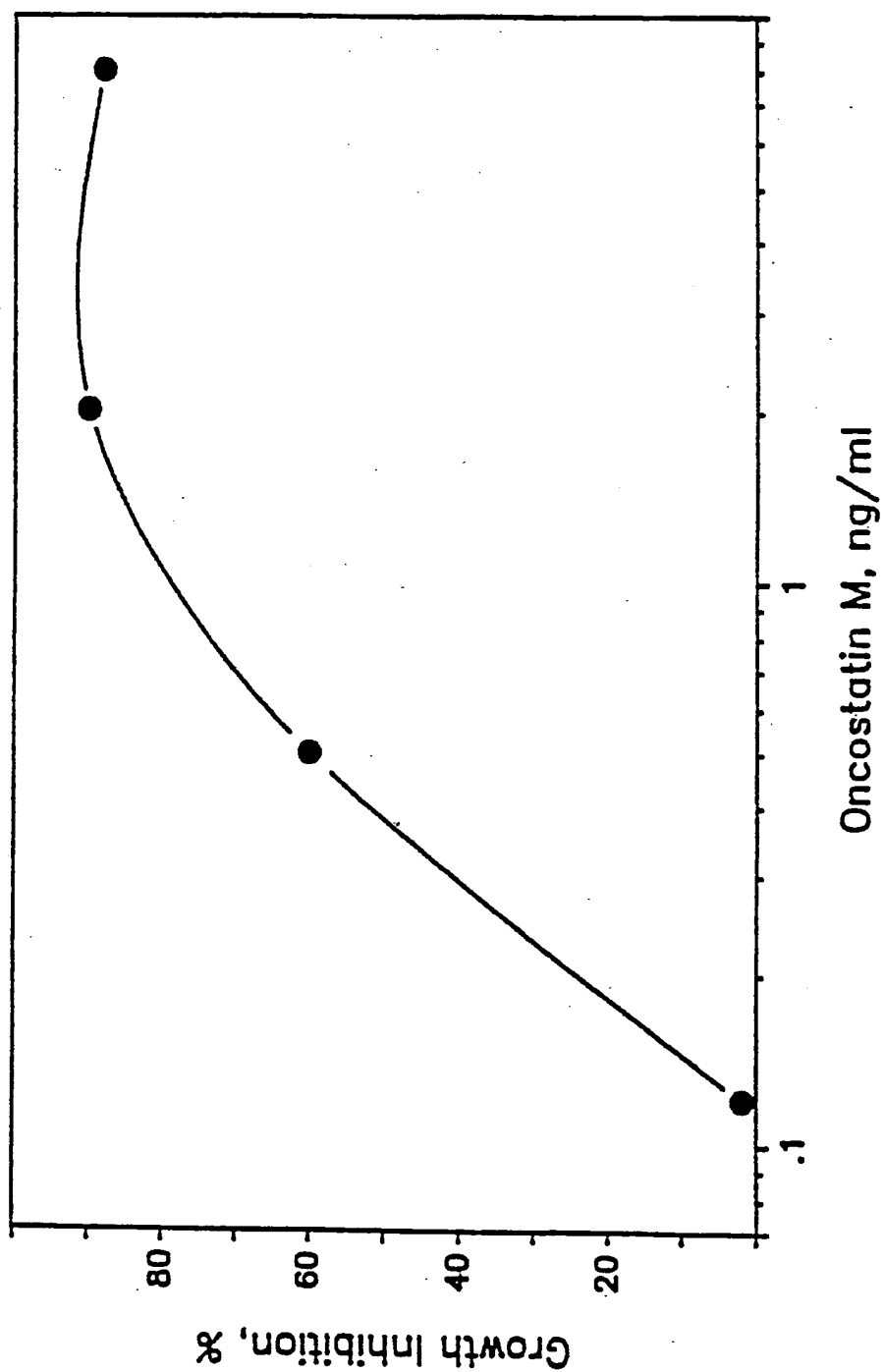


FIG. 8

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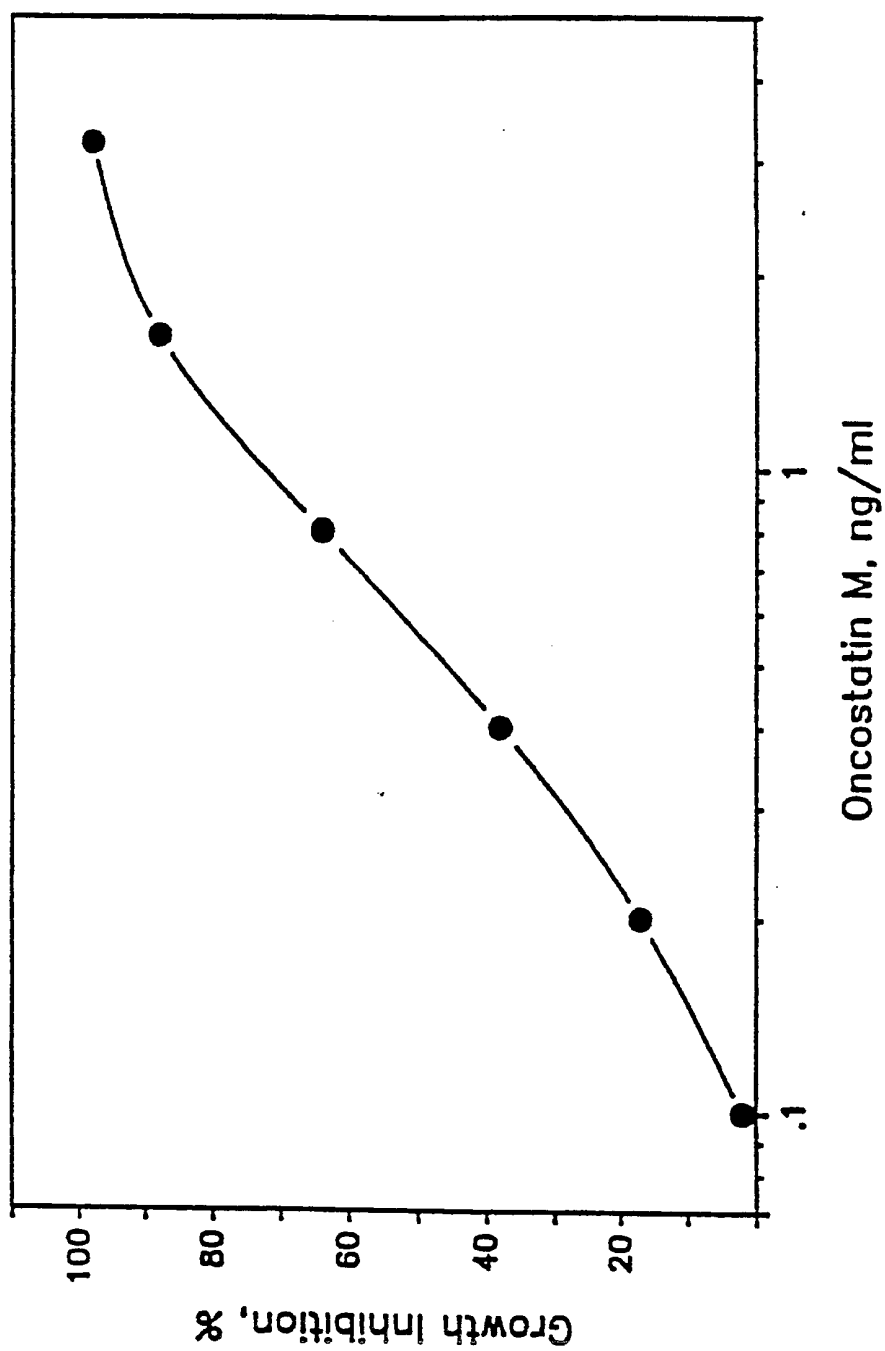
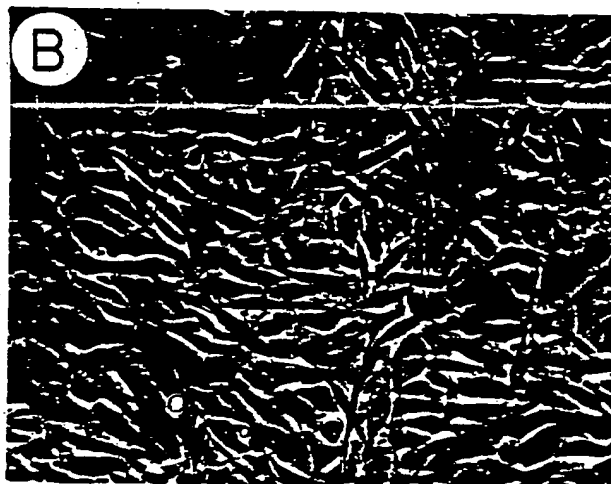
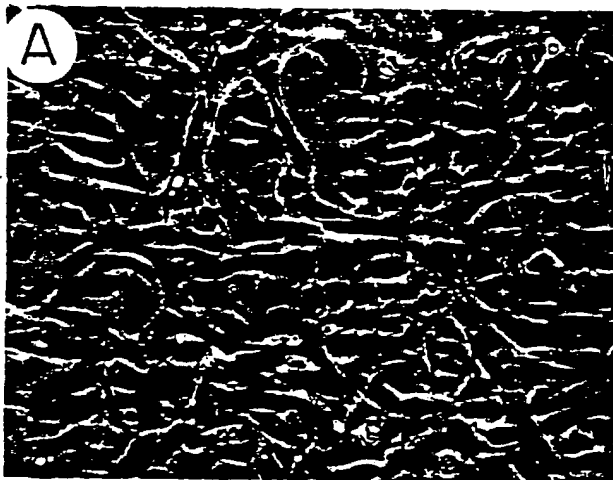


FIG. 9

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**FIG. 10A**



**FIG. 10B**

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Heterotypic Intercellular Adhesion

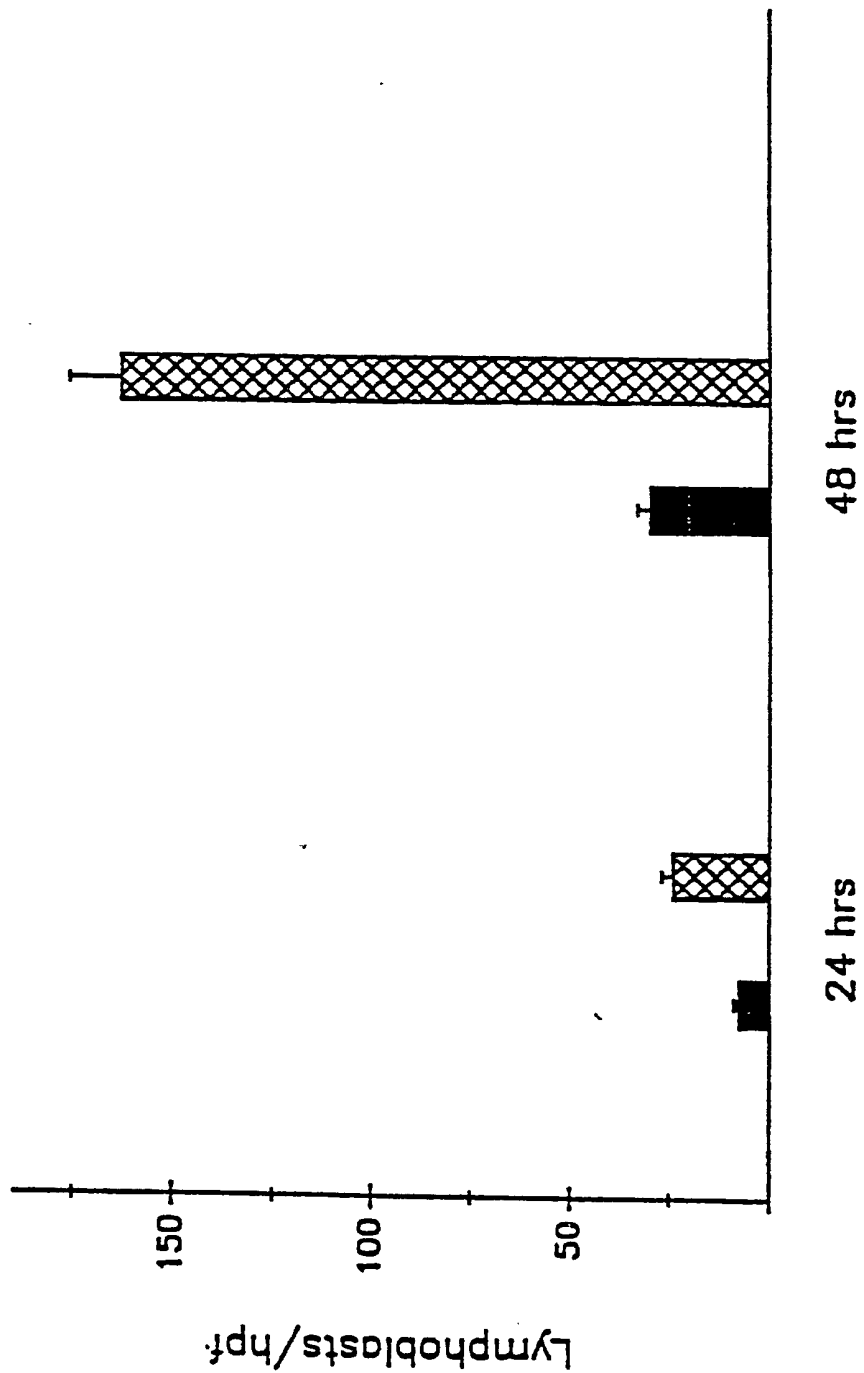
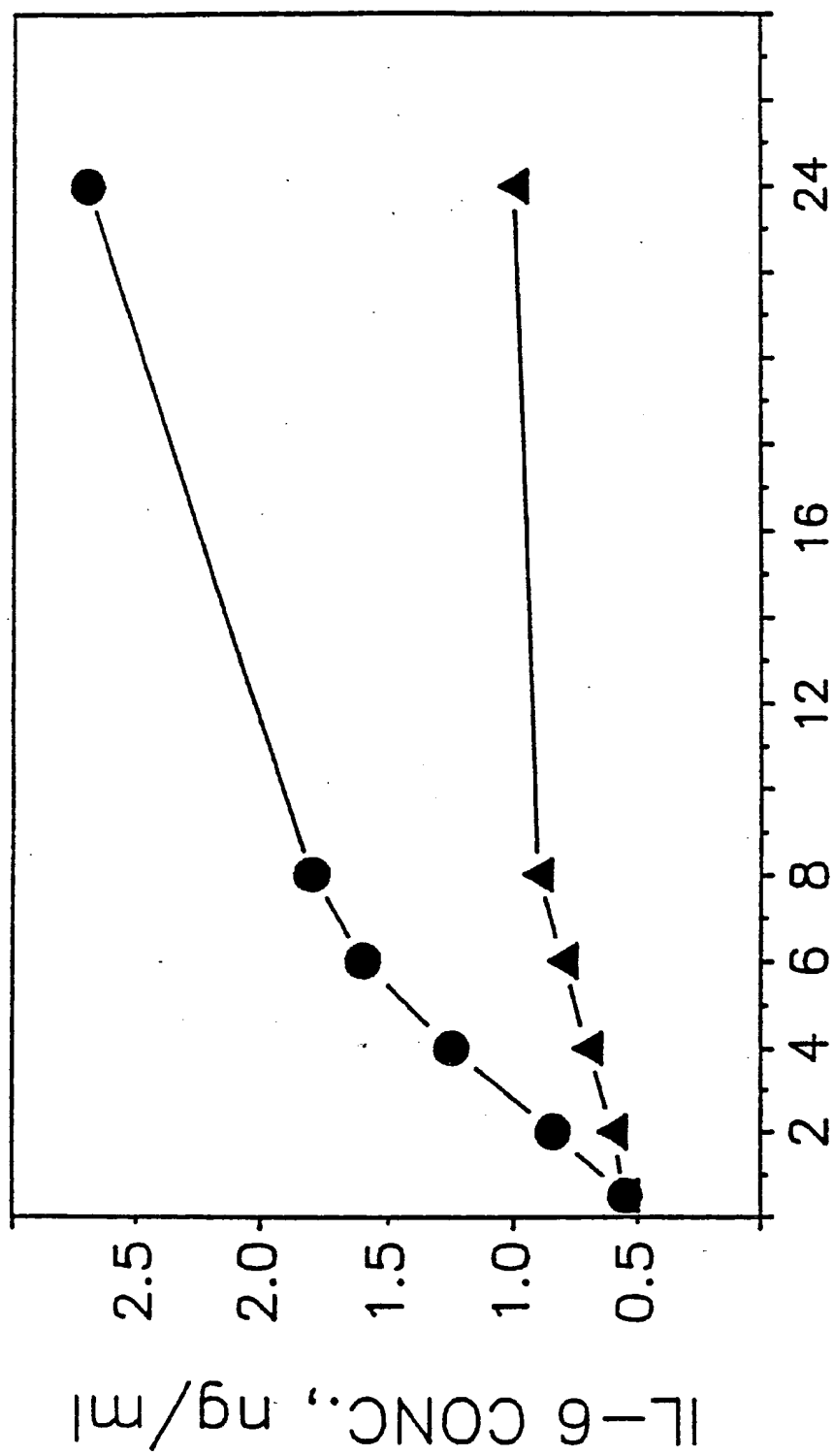


FIG. 11

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TREATMENT PERIOD, hrs  
FIG.12

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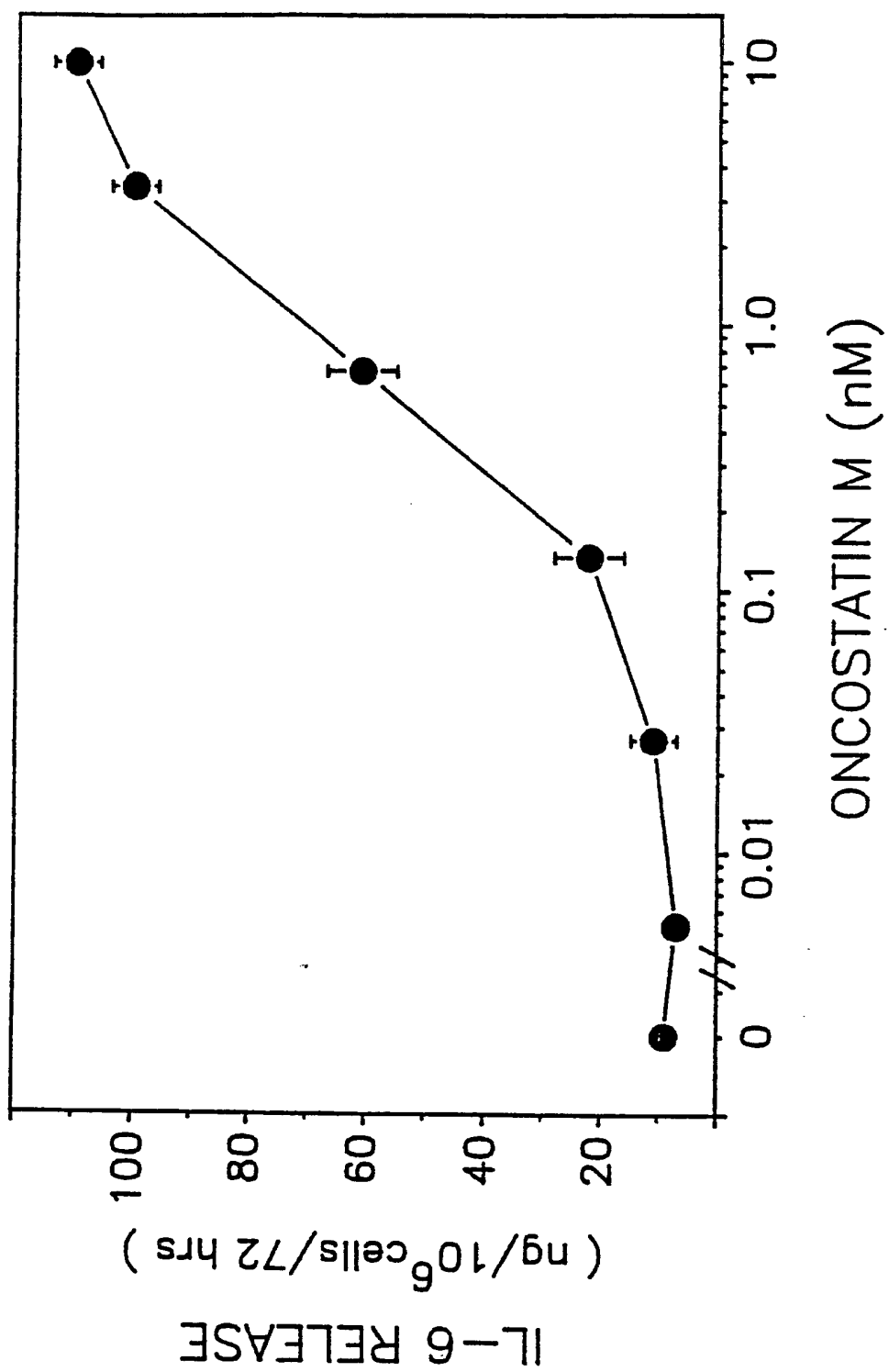
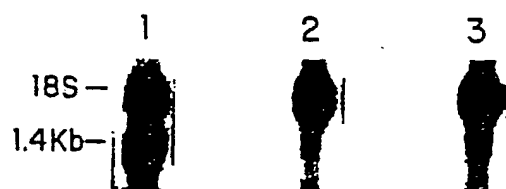


FIG.13



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**FIG. 14**



# INTERNATIONAL SEARCH REPORT

International Application No **PCT/US90/01907**

## I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) <sup>3</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC  
**IPC(5): A61K 37/00; A01N 25/34; A61K 37/22**  
**U.S. CL.: 514/12; 424/408, 450**

## II. FIELDS SEARCHED

### Minimum Documentation Searched <sup>4</sup>

Classification System

Classification Symbols

U.S.

514/12  
424/408, 450

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are Included in the Fields Searched <sup>5</sup>

Automated patent System and Dialog databases

## III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>14</sup>

| Category <sup>8</sup> | Citation of Document, <sup>10</sup> with indication, where appropriate, of the relevant passages <sup>11</sup>   | Relevant to Claim No. <sup>12</sup> |
|-----------------------|--|-------------------------------------|
| T                     | Molecular and Cellular Biology (United States), Volume 10(5), May 1990.<br>P.S. LINSLEY et al., "Cleavage of a hydrophilic C-terminal domain increases growth-inhibitory activity of Oncostatin M." pages 1882-90. See abstract.                       | 1-61                                |
| A                     | Journal of Immunology, volume 139(9), 01 November 1987, T.J. BROWN et al., "Purification and Characterization of Cytostatic Lymphokines Produced by Activated Human T Lymphocytes." Pages 2977-2983.   | 1-61                                |
| A                     | Proceedings of the Nation Academy of Sciences (USA), volume 83(24), December 1986, J.M. ZARLING et al., "Oncostatin M as a Growth Regulator Produced by Differentiated Histiocytic Lymphoma Cells," Pages 9739-43. See abstract (BIOSIS No. 83076929). | 1-61                                |
| A                     | EP, A, 0,290,948 (ONCOGEN), 17 NOVEMBER, 1988  | 1-61                                |

<sup>8</sup> Special categories of cited documents: <sup>13</sup>

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"Z" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search <sup>2</sup>

27 August 1990

Date of Mailing of this International Search Report <sup>3</sup>

**01 OCT 1990**

International Searching Authority <sup>1</sup>

ISA/US

Signature of Authorized Officer <sup>10</sup>

Thomas Cunningham, Ph.D.

## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

|   |  |      |
|---|--|------|
| T | Molecular and Cellular Biology, Vol. 9, No. 7, July 1989. N. MALIK, et al. "Molecular Cloning, Sequence Analysis, and Functional Expression of a Novel Growth Regulator, Oncostatin <u>M</u> ". Pages 2847-2853. | 1-61 |
|---|--|------|

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE<sup>1</sup>

This International search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ..... because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers ..... because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out<sup>1</sup>, specifically:

3. ☐ Claim numbers ..... because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING<sup>2</sup>

This International Searching Authority found multiple inventions in this international application as follows:

SEE ATTACHED

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

## Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

| III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET) |   |                                    |
|--|---|------------------------------------|
| Category *   | Citation of Document, <sup>16</sup> with indication, where appropriate, of the relevant passages <sup>17</sup>  | Relevant to Claim No <sup>18</sup> |
| Y  | Journal of Cellular Biochemistry, Supplement, Vol. O(12), 1988 P.S. LINSLEY, et al. "Identification of a membrane receptor for the growth regulator, Oncostatin <u>M</u> ", Page 227. See abstract.                         | 1-61                               |
| Y  | Journal of Cellular Biochemistry Supplement, Vol. O(12, Part A). 1988 T.J. BROWN, et al. "Oncostatin M Differentially Regulates the Action of Type 1 Transforming Growth Factor-beta (TGF-beta 1)", Page 194. See abstract. | 1-61                               |
| Y  | Journal of Cellular Biochemistry, Supplement. Vol. O(12 Part A), 1988. N. GUNDERSON, et al., "Expression of Oncostatin on and Properties of the Recombinant Protein", Page 224. See abstract.                               | 1-61                               |
| Y  | Journal of Cellular Biochemistry, Supplement. Vol. O(13 Part E) 1988. T. BROWN, et al. "Oncostatin Masa Unique Modulator of Endothelial Cell Surface Properties", Page 189. See abstract.                                   | 1-61                               |

ATTACHMENT TO PCT/ISA/210

VI. Observations Where Unity of Invention is Lacking:

Group I, claims 1-9, drawn to a method of inhibiting endothelial cell immunogenicity.

Group II, claims 10-17, drawn to a method of increasing plasmin activity.

Group III, claims 18-24, drawn to a method of inhibiting angiogenesis.

Group IV, claims 25-38, drawn to a method of improving organ transplantation.

Group V, claims 39-46, drawn to a method of treating thrombotic disease.

Group VI, claims 47-53, drawn to a method of treating Kaposi's sarcoma.

Group VII, claims 54-61, drawn to a method of inducing IL-6 synthesis.

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